1-1-2006

Nest success and brood habitat selection of the northern bobwhite in Southeast Iowa

Lisa M. Potter
Iowa State University

Nest success and brood habitat selection of the northern bobwhite in Southeast Iowa

by

Lisa M. Potter

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Ecology and Evolutionary Biology

Program of Study Committee:
David L. Otis, Major Professor
William R. Clark
Rolf R. Koford

Iowa State University

Ames, Iowa

2006

Graduate College
Iowa State University

This is to certify that the master's thesis of

Lisa M. Potter

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

TABLE OF CONTENTS

CHAPTER 1. GENERAL INTRODUCTION

Northern bobwhite (*Colinus virginianus)* are historically one of the most popular upland games species in North America, and in turn have been a focus of game management and research from as early as the 1920s (Stoddard 1931, Leopold 1933, 1936, Errington 1941, Scott 1985). Despite this vast collection of literature and accumulated knowledge, bobwhite populations have been declining throughout their geographic range for the past 30 years (Dimmick et al. 2002). The cumulative effects of advanced succession and monoculture farming are thought be the primary cause of declines (Burger 2001). The early successional grasslands used for nesting, the open, forb dominated grasslands used for brood rearing, and the brushy timber needed for escape and loafing cover are rare in today's modern agricultural landscape.

In response to the range wide declining population trend, the Southeast Quail Study Group Technical Committee recently initiated the Northern Bobwhite Conservation Initiative (NBCI), which is a nationwide habitat goal oriented plan to restore bobwhite populations (Dimmick et al. 2002). Through the implementation of improved habitat management practices and with the cooperation of federal, state, and private wildlife organizations, the NBCI predicts bobwhite decline could be halted by 2007 (Dimmick et al. 2002). Early successional maintenance of conservation reserve program (CRP) land, such as controlled burning and disking, the creation of field borders and hedgerows, and the conversion of cool season grasses, primarily fescue (*Festuca spp.*), to native grasses and forbs are a few of the management techniques suggested by the NBCI. Several studies have investigated the effects of prescribed burning and strip disking techniques on vegetation and bobwhite use (Taylor 1999*a*, Olinde 2000, Puckett et al. 2000, Taylor and Burger 2000), although few of these involved comparisons between managed and unmanaged landscapes. Studies evaluating responses in local bobwhite populations before and after the application of suggested management techniques are also lacking. Land managers lack reliable information regarding the minimum proportion of a landscape that should undergo management in order to elicit a positive response in local quail populations and therefore lack information necessary to make cost and time effective management decisions.

I studied bobwhite nest success and brood habitat selection in relation to landscape spatial patterns and habitat composition between managed and unmanaged landscapes. Bobwhite have a wide array of reproductive adaptations, such as the incubation of nests by males, renesting, and laying second or even third clutches, all of which provide bobwhite with high reproductive potential. However, until recently information on the effects of microhabitat vegetation characteristics and landscape composition on nest survival have been lacking (Taylor et al. 1999*b*). Additionally, habitat use by bobwhite broods is one of the most understudied components of bobwhite ecology (Roseberry and Klimstra 1984). As productivity may be one of the most important factors associated with changes in population size (Klimstra and Roseberry 1975, Roseberry and Klimstra 1984, Burger et al. 1995, Taylor et al. 1999*a*, Taylor et al. 1999*b*), identifying and managing quality nesting and brood habitats is vital to reversing the steady downward trend in bobwhite populations (Dimmick et al. 2002). The information gained from this study will help evaluate the influence of landscape composition and applied habitat management techniques on brood habitat selection and nest survival.

Thesis Organization

Chapter 1 provides a general introduction to my thesis research. Chapter 2 examines bobwhite nest success in relation to landscape spatial patterns and habitat composition on managed and unmanaged landscapes. Chapter 3 examines bobwhite brood habitat selection and brood survival in relation to landscape spatial patterns and habitat composition on managed and unmanaged landscapes. The last chapter provides general conclusions from my thesis research.

Literature Cited

Burger, L.W., M.R. Ryan, T.V. Dailey, and E.W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59(3):417-426.

Dimmick et al. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina. 96pp.

Errington, P.L. 1941. An eight-winter study of central Iowa bob-whites. The Wilson Bulletin 53(2)85-102.

Leopold, A. 1933. Game Management. Charles Scribner's Sons. New York, NY.

______. 1936. Quail population studies in Iowa and Wisconsin. Ecology 17(4):680-681.

Klimstra, W. D. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Olinde, M.W. 2000. Vegetation response to disking on a longleaf pine site in southeastern Louisiana. Pages 32-35 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail symposium. Tall Timbers Research Station, Tallahassee, FL.

Puckett, K.M., W.E. Palmer, P.T. Bromley, J.R. Anderson, Jr., and T.L. Sharpe. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Pages 26-31 *in* L.A. Brennan, W.E.

Palmer, Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Roseberry, J.L., and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, IL, USA.

Scott, T.G. 1985. Bobwhite Thesaurus. International Quail Foundation. Edgefield, SC.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, NY, USA.

Taylor, J.D., II. and L.W. Burger Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitat in Mississippi. Pages 7-15 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, JR., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999a. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 675-685.

______. 1999b. Microhabitat selection by nesting and brood rearing northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 686-694.

CHAPTER 2. NORTHERN BOBWHITE NEST SUCCESS IN RELATION TO LANDSCAPE SPATIAL PATTERNS AND HABITAT COMPOSITION

Lisa M. Potter and David L. Otis

ABSTRACT

The cumulative effects of advanced succession and monoculture farming are often cited as a primary cause of rangewide declines in northern bobwhite (*Colinus virginianus*) populations. A specific concern is the potential reduction in nest success and subsequent recruitment into fall populations. In 2003 and 2004, we compared nest success of radiotagged bobwhite in 2 landscapes in southeastern Iowa. The first was a 1452 ha state wildlife management area that since 1997 has been subjected to several management practices thought to promote quail recruitment. The second was a nearby township (2350 ha) used primarily for private agriculture production. Using program MARK, we estimated daily nest survival with the best approximating model that included an area and year effect only. The daily survival rate in 2003 was higher within the managed area (managed: 1.00, SE = 0.00; private: 0.953, SE = 0.023), whereas 2004 daily survival rates were similar between sites (managed: 0.969, SE=0.011; private: 0.964, SE = 0.011). Microhabitat characteristics, landscape composition and configuration within 210 m of a nest, and applied management techniques on Lake Sugema Fish and Wildlife Area (LSWA) did not have a measurable effect on nest success. Although the available grassland on the managed area was nearly twice that available on the private study site, the landscape within 210 m of a nest contained at least 30% grassland on both areas. This suggests that bobwhite may in fact make nest site selection choices on the landscape scale, even though this may not ultimately affect success. As applied habitat management techniques did not prove to enhance nest success on areas

that were already supporting quail populations, managers should focus on creating additional usable space to increase bobwhite abundance.

Key Words: edge feathering, habitat management, Iowa, landscape, nest success, northern bobwhite, prescribed burning, program MARK, spatial patterns, strip disking, usable space

INTRODUCTION

Although northern bobwhite (*Colinus virginianus*) have been a focus of upland game management and research from as early as the 1920s (Stoddard 1931, Leopold 1933, 1936, Errington 1941), populations continue to steadily decline throughout the majority of their geographic range in the continental United States. The Breeding Bird Survey (BBS) showed an average rangewide decline of 3.8% per year in bobwhite breeding numbers from 1982 to 1999 (Dimmick et al. 2002). The cumulative effects of advanced succession and monoculture farming are thought be the primary cause of bobwhite declines (Burger 2001). Bobwhite are a relatively sedentary species that require 3 essential habitat components. The early successional grasslands used for nesting, the open, forb dominated grasslands used for brood rearing, and the brushy timber needed for escape and loafing cover are rare in today's modern agricultural landscape. Farming practices have changed drastically over the years. Agricultural land has evolved into expansive monoculture crop fields as land suitable for cultivation becomes more valuable and farming machinery becomes more technologically advanced. The reduction in spatial heterogeneity in the landscape has paralleled this change in farming practices, and as a result the quantity and quality of edge habitat preferred by northern bobwhite has also diminished.

In response to the rangewide declining population trend, the Southeast Quail Study Group Technical Committee recently initiated the Northern Bobwhite Conservation Initiative (NBCI), which is a nationwide habitat goal oriented plan to restore bobwhite populations to densities estimated during the baseline year of 1980 (Dimmick et al. 2002). The plan sets out specific habitat management goals for the 15 Bird Conservation Regions that constitute the bobwhite geographic range. Through the implementation of improved habitat management practices, and with the cooperation of federal, state, and private wildlife organizations, the NBCI predicts bobwhite decline could be halted by 2007 (Dimmick et al. 2002). The goals set for increasing bobwhite populations in Iowa and surrounding states focus on management and maintenance activities that will develop quality nesting, brood rearing, roosting and woody cover habitat. Early successional maintenance of Conservation Reserve Program (CRP) land, such as controlled burning and disking, the creation of field borders and hedgerows, and the conversion of cool season grasses, primarily fescue (*Festuca spp.*), to native grasses and forbs are a few of the management techniques suggested by the NBCI.

Several studies have investigated bobwhite nesting habits and success in the upper mid-west (Klimstra 1950, Klimstra and Roseberry 1975, Suchy and Munkel 1993, Burger et al. 1995*a*, Taylor et al. 1999*b*). These studies suggest that the amount of litter coverage and the height of vegetation surrounding nests can influence nest success at the microhabitat scale (Stoddard 1931, Klimstra and Roseberry 1975, Taylor et al. 1999*b*). At the landscape scale, the proportion and spatial arrangement of grasslands can be important (Taylor et al. 1999*a*, White et al. 2005). Bobwhite have a wide array of reproductive adaptations, such as the incubation of nests by males, renesting, and laying second or even third clutches, all of which provide bobwhite with high reproductive potential. Roseberry and Klimstra (1984) found that the ratio of chicks hatched to females was the reproductive index most closely associated with recruitment into fall populations. As it is generally accepted that an increase in usable space will result in an increase in abundance (Guthery 1997), increased availability of quality nesting habitat should lead to more chicks hatched to females, which in turn may increase bobwhite recruitment.

Although nest site selection and large scale habitat characteristics describing bobwhite habitat needs have been extensively investigated, information for land managers about where and how to increase usable space is lacking. Several studies have investigated the effects of prescribed burning and strip disking techniques on vegetation and bobwhite use (Taylor 1999*a*, Olinde 2000, Puckett et al. 2000, Taylor and Burger 2000, Greenfield et al. 2003), although few of these involved comparisons between managed and unmanaged landscapes. Additionally, land managers rarely have the available resources to evaluate bobwhite population densities before and after the implementation of management techniques, therefore losing the potential to directly couple local landscape changes with changes in population densities. Without information regarding how and at what spatial scale habitat management positively affects bobwhite in localized areas, the means to increase rangewide populations will remain elusive.

The goal of my study was to estimate and compare the probability of nest success as a function of local habitat composition and structure and between managed and unmanaged landscapes. The information gained from this study will help evaluate the influence of landscape composition and applied habitat management techniques on nest success. Specifically, my objectives were: 1) describe and compare nest site microhabitat characteristics and surrounding landscape spatial patterns and composition, and 2) estimate and compare the probability of nest success as a function of microhabitat and landscape spatial patterns and composition between managed and unmanaged landscapes.

METHODS

Study Areas

The project was conducted from February – October 2003 and 2004 on the Lake Sugema Fish and Wildlife Area (LSWA) and selected areas within Harrisburg Township in VanBuren County in southeastern Iowa. The study areas are located in the southern Iowa Drift Plain.

LSWA is a 1464 ha public wildlife area that is part of the Indian Creek-Van Buren Watershed Project sponsored by the Natural Resources Conservation Service (NRCS) and is managed by the Iowa Department of Natural Resources (IDNR). Land acquisition began in 1988 and was essentially completed by 1992. The majority of the cropland that was acquired was previously enrolled in CRP. In 1992, approximately 254 ha in LSWA were flooded to provide fishing recreation. The remaining area consists of grassland, pasture, crop fields, and timber. Approximately 263 ha are leased out to private farmers and are primarily planted in wheat, soybean rotation, and hay. LSWA is open to hunting and fishing, with the exception of a 157 ha wildlife refuge area.

In 1997, the IDNR began an intensive bobwhite management regimen primarily designed to increase the local populations of northern bobwhites by improving bobwhite winter, nesting, and brooding habitats. Management techniques include strip disking/spraying, prescribed burning, edge feathering of timber stands, and planting food plots.

Spraying strips in grassland habitat with herbicides such as glyphosate (Roundup® or Roundup Ultra®) creates the same desired effects as mechanical strip disking (C. Steffen, pers. comm.). Both techniques result in the increase of the bare ground and forb component, an increase in arthropod abundance, and a decrease in litter cover and litter depth, all of which provide increased foraging habitat and protective cover for chicks and adults during the breeding season (Greenfield et al. 2003). Approximately 23 ha of disk/spray strips (hereafter strip disks) have been created in the LSWA. Strips were applied to the landscape at nonrandom lengths and at approximate widths of 10 to 18 m, with the majority (81%) 10 m wide. Strips were created utilizing both mechanical and chemical means on LSWA. All strips, regardless of technique, length, or width, were combined for analyses.

Prescribed burning sets back the successional stage of an area while simultaneously increasing plant diversity and invertebrate abundance and decreasing litter cover and litter depth (Hurst 1970, Greenfield et al. 2003). At least one third of the 720 ha designated in the burning plan for LSWA are burned each year. The IDNR has used edge feathering on approximately 34 km of older timber edges. Edge feathering is created by cutting partway through trees and shrubs along timber stand edges so the tops fall to the ground with sufficient connective material remaining to keep the tree alive. Edge feathered timber stands create living brush piles that provide year-round escape cover and loafing areas for bobwhite (Daily and Hutton 2003). The food plots on LSWA are planted to corn, sorghum, millet, wheat or soybeans, either planted as a single crop or in combinations, and are not controlled for weeds. Twenty-one food plots totaling 20 ha have been planted on LSWA.

LSWA is bordered along the northeast by the Shimek State Forest and the Lacey-Keosauqua State Park. The 360 ha Shimek State Forest is a managed multiple-use area for timber products, wildlife habitat, and recreation. The majority of the Lacey-Keosauqua State Park consists of timber habitat that is managed for recreation. The area immediately surrounding LSWA to the north, south and west is primarily devoted to private agricultural production. The majority of the cropland is either planted in corn and soybean rotation, or hay. The remaining land is primarily grazed or ungrazed pasture.

The second study area was a 2360 ha area in Harrisburg Township (HTA), located approximately 16 km northeast of the LSWA. This area is primarily devoted to private agricultural production of corn and soybeans, planted in rotation, and hay. The remainder of the HTA consists of grazed pasture, land enrolled in CRP, and timber. The exact acreages and parcels used in the study area were dependent upon those landowners who granted permission to access their land. With the exception of 4 food plots planted by landowners, the HTA has not undergone any known habitat management for bobwhite populations.

Bobwhite Capture

Bobwhites were trapped continuously from 1 February to approximately 1 August in 2003 and 2004 using 3 trapping methods. In late winter and early spring, with the assistance of trained bird dogs, we extensively searched both study areas for bobwhite coveys. Behavioral signs such as roosting sites or bobwhite track marks were also used to locate bobwhite. We used walk-in funnel traps (Stoddard 1931:443) baited with cracked corn from 1 February to approximately 7 April in 2003 and 2004 to trap both males and females. In 2003, traps were placed non-randomly in brushy cover known or thought to be used by bobwhites. In 2004, to distribute the late winter and early spring trapping effort evenly and to facilitate the capture of a representative sample of the population, both study areas were divided into 12 sections approximately 197 ha each. Ten to 20 walk-in funnel traps were distributed throughout each section, localized in areas where scouting occasions indicated the presence of bobwhite in the immediate area. Each trap locale was pre-baited with cracked corn for a period of 4 days followed by 4 days of active trapping. One section at a time was actively trapped on each study area until trapping was attempted in all 12 sections on each area. In 2004, following the capture and the attachment of a radiocollar on 1 or more individuals from a covey, we used nightlighting techniques (Truitt and Dailey 2000) to attempt to capture the remaining individuals of that covey.

During the breeding season, cock-and-hen traps (Stoddard 1931:99) were used to capture males. Traps were placed non-randomly in locations where male bobwhite had been previously seen or heard. Electric callers, playing a loop-back tape of assembly calls, were placed directly next to the trap to attract male bobwhites. Traps were checked 2-3 times daily, once at approximately 9 AM, again at midday if a bobwhite was seen around the trap during the morning check, and at sunset. The third trapping technique was targeted at females and involved nightlighting radiomarked males which were known to be paired with an unmarked female. In order to quickly identify the pairing of a radiomarked male with an unmarked female, weekly flushes of collared single males were conducted until the male was found with a radiomarked or unmarked female. The Universal Transverse Mercator (hereafter UTM) coordinates were recorded at each successful trap site.

Captured bobwhites were aged, sexed, weighed and marked with a unique #7 aluminum leg band. Each bobwhite weighing greater than 150 g was fitted with a 5.9 g, mortality sensing, pendant style necklace radio transmitter (Advanced Telemetry Systems, Isanti, MN) and released on site if capture occurred before sunset. Bobwhites captured after sunset were held overnight and released at the trap site the following morning. All procedures were approved by the Iowa State University Committee on Animal Care.

Radio-Telemetry

Radio-marked bobwhites were monitored 1-2 days per week from a vehicle mounted null-peak radio telemetry system beginning 21 March in 2003 and 13 February in 2004 until 31 March to monitor mortality status only. Bobwhites were located 3-7 days per week from 1 April until 23 October 2003 and 27 October in 2004. Locations were collected for nesting and non-brooding adults 3-5 days per week. Locations for brooding adults were collected 7 days per week for a period of 28 days beginning the day after hatching. After 28 days, locations were collected 5 days per week for brooding adults until the adult was no longer associated with a brood or the formation of a covey with additional bobwhite occurred in late September or October.

I used the homing technique (White and Garrott 1990:42) to encircle the birds from a distance of 15-20 m. In 2003, after locating a bobwhite, I recorded the bearing and distance from my location to the bobwhite on a piece of flagging which was then tied to nearby vegetation. Locations for each bobwhite were also plotted on aerial photos of the study areas. I returned to the location of the flagging within 7 days and used the previously recorded bearing and distance estimates to collect the UTM coordinates at the actual location where the bobwhite was previously found. Hand-held Garmin Etrex® and Etrex Venture® Global Positioning System (GPS) units were used to enable the transfer of information to a Geographical Information System (GIS) color infrared photograph of the study areas. In 2004, after locating a bobwhite using the homing technique, I aligned myself in a cardinal direction to the bobwhite from a distance of 15-20 m, and the UTM coordinates for the location of the bobwhite were recorded by adding or subtracting the distance to the bobwhite from the appropriate northing or easting UTM coordinate of my location.

To obtain a representative sample of diurnal habitat use by bobwhite, each day was stratified into 3 blocked time segments. The first block of time began at sunrise and continued for 3 ½ hours. The third block of time began 3 ½ hours before sunset and concluded at sunset. The second time block covered the afternoon hours between the first and third time blocks (Hawkins 2000). I collected consecutive locations on an individual bobwhite during different time blocks, as well as at different times within the specific blocks of time, resulting in at least 1 location within each time block every 7 days.

The onset of incubation was suspected when an individual was found in the same location for 2 consecutive days during the breeding season. Flagging was tied to vegetation ≥10 m away from the estimated nest location. When a telemetry location indicated the adult was away from the suspected nest location, the nest was confirmed and the clutch size and UTM coordinates of the exact nest location were recorded. I monitored incubation status ≥5 times a week and returned to the nest once every 7 days in 2003 and once every 10 days in 2004 to monitor the status of the clutch. Nests were considered successful if ≥1 egg hatched. A nest was considered destroyed if ≥1 egg was destroyed and the incubating adult did not return to the nest. The area within approximately 10 m of a destroyed nest was searched for evidence of a nest predator (Sargeant et al. 1998). Nests were considered abandoned if all eggs remained intact, but incubation by the surviving adult did not resume within 7 days (Taylor et al. 1999*a*).

UTM coordinates of all mortality locations were collected within 1-2 days after a mortality signal was activated. Mortalities were classified as avian predator, mammalian predator, human (e.g., mowing), or unknown. The location of the predation event was searched for signs of predation type by concentrically searching within 10 m of the radio transmitter. Predation type was determined from signs remaining at mortality sites, such as predator track marks, bobwhite remains, and markings or indentations on the radio transmitter. Predation type was classified as unknown if there was not sufficient evidence at the mortality site to make a determination.

Local Vegetation Measurement

Within 7 days of nest termination, I measured vegetation height, total percent canopy coverage, and relative percent canopy coverage, with overlapping percentages, of bare ground, litter, grasses, forbs, and woody vegetation <1 m in height within a 50- x 50 cm sampling frame (modified from Daubenmire 1959) centered around the nest bowl. I also collected a litter depth measurement adjacent to the nest bowl, as well as the dominant vegetation *genus* within the sampling frame. A visual obstruction pole (Robel et al. 1970) was placed directly in the nest bowl and I measured the visual obstruction reading (VOR) of the pole by vegetation from 4 m in each cardinal direction. All canopy coverage measurements were repeated at 2 and 4 m in each cardinal direction. Litter depth measurements were repeated along the same transects at 1, 2, 3, and 4 m.

GIS Study Area Coverages

I used color infrared aerial photographs taken in 2002 to classify the study areas into habitat types. I hand-digitized to a minimum patch size of 0.01 ha and assigned habitat types to each study site and an approximate 1.6 km buffer surrounding each site using ArcView GIS 3.3. A habitat patch is defined as an area that consists of relatively homogenous vegetation that differs from its surroundings (Otis 1998). Study sites were classified into 6 habitat types (Table 1): a. Cornfields, b. Grassland, c. Pasture, d. Roadside, e. Small Grain Structure, f. Timber. Lakes on LSWA were excluded from the total available habitat, while farm ponds on LSWA and HTA were collapsed into the habitat category in which they were located. All habitat categories except crop fields were ground-truthed only in 2003, and crop fields were ground-truthed in both 2003 and 2004. On LSWA, I collected the UTM coordinates for all strip disks, fence lines, and areas of edge feathering. However, due to the restrictions set by private landowners, the coordinates of the fence lines on private land were not obtained on site and were estimated from the color infrared photographs.

Landscape Metrics

I used the Identify Features within a Distance (Jenness Enterprises) extension for ArcView GIS to calculate distances from the nest site to the nearest patch edge of each habitat type, fence line, strip disk, edge feathering, and the nearest field burned the current and previous year, within a 210 m buffer area centered around the nest. The buffer distance is the diameter of a 12 ha circle, which is an estimate of the area used by bobwhite during laying and incubation (Taylor et al. 1999*a*). To quantify the landscape composition within the buffer, I calculated the percent of each habitat type and the total edge density. I also recorded the type, size, and edge density of the nest patch, and the percent of each habitat type within the entire study area. The inclusion of the specific landscape metrics was based upon their reported influence on the nest success of grassland birds (Burger et al. 1990, Mankin and Warner 1992, Clark et al. 1999, Schmitz and Clark 1999, Taylor et al. 1999*a*,*b*; Bergin et al. 2000, Kuehl and Clark 2002, and Staller et al. 2002).

STATISTICAL ANALYSES

Microhabitat and Landscape Characteristics

PROC UNIVARIATE (SAS Institute 2004) was used to obtain summary statistics including the mean, standard error, range, and the distribution for all microhabitat and landscape metrics. All microhabitat and landscape metrics were checked for collinearity using the Pearson correlation coefficient and were considered highly correlated when the Pearson correlation coefficient was ≥ 0.7 (Quinn and Keough 2002).

I used general linear models to examine differences in vegetation structure and composition and differences in landscape metrics between study areas, years, and fate of nesting attempt (PROC GLM; SAS Institute 2001). I treated the mean vegetation and landscape metrics as the response variables and the study site (LSWA or HTA), year (2003 or 2004), and nest fate (Successful or Unsuccessful) as the explanatory variables. PROC GLM was also used to examine the effects of applied management techniques on nest fate in LSWA (Cody and Smith 1991). Canopy coverage metrics and habitat type proportions were arcsine transformed while vegetation height, litter depth, VOR, and landscape distance metrics were log transformed (Fowler et al. 1998) as needed to satisfy the normal distribution and equal variance assumptions of GLM. Untransformed means and errors are reported for ease of interpretation. In 2003, all monitored nests on LSWA were successful, therefore I was unable to test for year*fate and year*site effects. I used a site*fate interaction to test for differential site effects on vegetation structure and composition and landscape metrics. When I observed a significant F-test ($P < 0.10$) for main effects or interactions I tested for differences among levels of that effect with a Tukey-Kramer multiple comparison (SAS Institute 2001).

Nest Success

Daily survival of nests was estimated using the nest survival model in program MARK (Dinsmore et al. 2002). Traditional Mayfield daily nest survival estimates (Mayfield 1961) require the assumption of constant daily survival and can limit the use of multiple covariates with small sample sizes. Alternatively, program MARK can estimate temporal variation in daily survival rates and model nest survival as a function of time specific covariates (Dinsmore et al. 2002). I assumed that nests were correctly aged when first found, nest fates were correctly determined, nest discovery and nest checks did not influence survival, and nest fates were independent (Dinsmore et al. 2002).

I standardized 20 May as day 1 in the nesting season for both years as this was the earliest date an observed bobwhite was found to be incubating in 2003 and 2004. I define the nesting season as the period between the earliest incubation initiation date for all monitored nests and the termination (i.e., successful or unsuccessful) date of the last monitored nest. The bobwhite nesting season in this study was active from 20 May to 6 September. In 2003 on the HTA, a female attempted to incubate a nest for 61 days. The reason for the extended incubation period by this particular hen is unknown, however Stoddard (1931:35-36) reported observing similar behavior. The average incubation period for bobwhite is 23 days, therefore this nest was considered unsuccessful at 23 days of incubation for the analyses.

I developed four sets of *a priori* candidate models (Burnham and Anderson 2002) to explore relationships between nest success and; 1) temporal variation within and among years and sex of the incubating adult (basic), 2) microhabitat composition and structure (microhabitat), 3) landscape composition and structure (landscape composition), and 4) predator movement and foraging efficiency (landscape configuration). Habitat metrics (Table 2) were selected based upon review of published literature and personal observations during the study. Model analyses involved a two-stage, hierarchical process (Table 3). First, the model with the smallest Akaike's Information Criterion (AIC_c) value within Set 1 (basic) was selected as the best approximating temporal model and was carried throughout the model selection analyses. I evaluated the degree of support for each model using AIC_c corrected for small sample sizes (Burnham and Anderson 2002). Models with $\Delta AIC_c \leq 2$ were considered to have strong support. Second, effects from the best 2 models from each set of candidate models were included into a final analysis to determine which model (i.e., basic, microhabitat, landscape composition, or landscape configuration) best estimated the variation in nest success on LSWA and HTA in 2003 and 2004.

The first set of models explored the temporal (constant or daily) and annual variation within study sites as well as variation associated with the sex of the incubating adult. Although bobwhite nest survival has been found to decrease during the course of the nesting season (Klimstra 1950, Klimstra and Roseberry 1975), I was unable to separately estimate survival estimates for early, mid, and late season nesting attempts due to the small sample size of nesting attempts within both study sites and years. Males incubate 22 to 28% of all nests in a given season (Klimstra and Roseberry 1975, Burger et al. 1995*a*). Previous studies have suggested that survival of female incubated nests may be higher than that of male incubated nests, while other studies have reported no differences in success rates between female and male incubated nests (Burger et al. 1995*a*).

The second set of candidate models included microhabitat covariates such as vegetation height and density, percent total canopy, percent coverage of litter, grasses, forbs, and woody vegetation, and litter depth. Vertical cover, canopy cover of grasses and forbs, and the heterogeneity of the composition and structure of the vegetation are all characteristics that are believed to affect grassland birds (Wiens 1974). Schroeder (1985) suggested that optimal bobwhite nesting cover should have 50% herbaceous canopy cover. Other studies have suggested bobwhite prefer nest sites with at least one year of accumulated litter and vegetation that is taller and more dense than surrounding habitat (Stoddard 1931, Klimstra and Roseberry 1975, Burger et al. 1990, and Taylor et al. 1999*b*).

The third set of candidate models included landscape composition covariates. Covariates included the percent of each habitat type within the buffer area. Taylor et al. (1999*a*) found bobwhite home ranges had shorter distances to grassland habitat than random points within the surrounding landscape, suggesting the importance of the availability and proximity of grassland habitat for breeding. White et al. (2005) stated that optimal bobwhite habitat contains at least 30% grassland within a home range. Previous studies have shown that bobwhite demonstrate a preference for idle habitat and avoidance of cropland for nesting sites (Klimstra and Roseberry 1975, Taylor 1999*a*). In Illinois, Klimstra and Roseberry (1975) found that nest density was highest in roadside habitat, although nest survival was low.

The fourth set of *a priori* candidate models included covariates such as distance to timber, grassland, and cornfield patches, the edge density of the nest patch, as well as the total edge density of the entire 210 m buffer, the percent of timber and grassland habitat within the buffer, and the total canopy coverage and VOR at nest sites. These covariates are hypothesized to be related to predator movement and foraging activities (Mankin and Warner 1992, Clark et al. 1999, Schmitz and Clark 1999, Bergin et al. 2000, Kuehl and Clark 2002, Staller et al. 2002). Bobwhite often use timber edges as escape and loafing cover, but timber patches have also been suggested as habitat that harbors potential nest predators, such as raccoons (*Procyon lotor*), and is therefore detrimental to nest survival (Guthery et al. 2001). Bobwhite prefer nest sites near edges (Stoddard 1931), and predators often use edges as travel corridors (Kuehl and Clark 2002). Nest patch size and nest concealment have also been reported as affecting predator foraging efficiency (Mankin and Warner 1992).

An additional set of *a priori* candidate models was used to estimate nest success as a function of the applied management techniques on LSWA (Table 4). Covariates included the distance from a nest site to the nearest patch that was burned the previous year, the nearest patch that was burned 2 years previously, the nearest strip disk, and to the nearest area of edge feathering.

RESULTS

Microhabitat Characteristics

Some microhabitat vegetation composition and structure metrics at nest sites (Table 5) differed between study areas and years (Table 6), but did not differ between successful and failed nests (Fig. 1 and 2). Percent litter was significantly greater on LSWA ($p=0.027$). Height of vegetation was greater in 2003 ($p = 0.042$), while litter depth was significantly greater in 2004 ($p = 0.004$). Litter depth and percent forb canopy coverage were the only microhabitat metrics with significant area*fate interactions. Failed nests on LSWA had significantly greater litter depth ($\bar{x} = 57.79$ mm, SE = 10.23, n=8) than failed nests on the HTA ($\bar{x} = 24.46$ mm, SE = 4.24, n = 14), while average litter depth did not differ between successful nests found on LSWA ($\bar{x} = 38.81$ mm, SE = 7.74, n = 12) and HTA ($\bar{x} = 28.45$ mm, SE = 3.35, n = 8). Forb canopy coverage of successful nests was similar between sites (LSWA: $\bar{x} = 31.56$, SE = 5.03, n = 12; HTA: $\bar{x} = 30.96$, SE = 9.14, n = 8), whereas failed nests on LSWA ($\bar{x} = 40.03$, SE = 4.73, n = 8) had significantly greater forb coverage than failed nests on HTA ($\bar{x} = 19.57$, SE = 4.52, n = 14). VOR, total canopy, grass, and woody canopy coverage did not differ between sites, years, or fate of nests.

Landscape Characteristics

The LSWA had a greater proportion of grassland, and less small grain structure and cornfields than HTA (Fig. 3). The proportions of pasture, roadside, and timber habitat types were similar between areas.

Distance measurements from a nest to the nearest cornfield, small grain structure, pasture, and roadside patch were highly correlated (Pearson correlation coefficient ≥ 0.7) with the corresponding percent habitat type within the 210 m buffer. Therefore, these metrics were not used in the GLM analyses. Distance from a nest site to the nearest edge was used in the analyses rather than its correlate, size of the nesting patch.

Landscape composition within a 210 m buffer centered around nest sites (Table 7) was different between areas, fate of nests, and years (Table 8). Percent corn was significantly greater ($p = 0.002$) on HTA ($\bar{x} = 17.92$, SE = 4.32, n = 22) than LSWA ($\bar{x} = 0.89$, SE = 0.61, n = 20) while percent grass was greater ($p = 0.013$) on LSWA (LSWA: $\bar{x} = 55.30$, SE = 5.24, n = 20; HTA: $\bar{x} = 36.13$, SE = 4.16, n = 22). Percent grain and percent timber differed between years. Percent grain was greater in 2003 and percent timber was greater in 2004. Percent roadside and small grain structure did not differ between areas, however percent roadside and small grain structure were the only variables to significantly differ between successful and failed nests. Successful nests had a significantly greater percent of both small grain structure (Successful: $\bar{x} = 19.01$, SE = 3.22, n = 20; Failure: $\bar{x} = 10.22$, SE = 3.29, n = 22) and roadside habitats (Successful: $\bar{x} = 1.99$, SE = 0.33, n = 20; Failure: $\bar{x} = 1.14$, SE = 0.26, n = 22) within the buffer (Fig. 4), however the proportion of the surrounding roadside habitat for both successful and unsuccessful nests was less than 2.0%.

Landscape configuration within a 210 m buffer (Table 9) did not differ between areas, fate, or years (Table 10). The distance from a nest to the nearest timber patch was the only metric with a significant area*fate interaction, although there were no significant main effects between areas or between successful and failed nests (Fig. 5). The distance from a nest to the nearest timber patch was greater on LSWA for successful nests ($\bar{x} = 104.60$ m, SE = 18.42, n = 12) compared to failed nests ($\bar{x} = 56.16$ m, SE = 23.73, n = 8), however distances to the nearest timber patch were similar for successful ($\bar{x} = 60.82$ m, SE = 18.73, n = 8) and failed ($\bar{x} = 63.75$ m, SE = 14.54, n = 14) nests on HTA. The mean distances from a nest to the nearest management technique on LSWA were not different between fate of nests or years (Table 10).

Nest Success

We captured and radiotagged 53 (25 M, 28 F) bobwhite on the LSWA and 51 (31 M, 20 F) in the HTA during 2003-04. The mean location estimate error was 8.50 m (SE = 1.17). I monitored 42 nests in 2003 (n = 11) and 2004 (n = 31). A total of 13 nests (LSWA: n= 9, HTA: n=4) were found outside of the study areas. However, due to the small sample size of nesting attempts and the relatively close proximity of the off-area nest locations, these nests were included into the analyses. The final sample included 20 successful nests and 22 unsuccessful nests. Twenty nests were monitored on LSWA and 22 on HTA. Males incubated 4 (36%) nests in 2003 and 8 (26%) nests in 2004. In 2004, 2 females attempted to renest in HTA after the depredation of their first attempt. One female attempted 3 nests, allowing the male to incubate her first nest of the season which resulted in a successful hatch. The hen then incubated the second and third nesting attempts, however both nests failed. There were also 2 females on LSWA that attempted to renest after failed first attempts in 2004. Only one of the hens successfully produced a brood from the renesting attempt. The majority of nests were found in grassland habitats, followed by pasture and roadside (Fig. 6), although the highest density of nests per hectare was found in roadside habitats on both sites.

In 2003, all monitored nests were successful on LSWA, while 4 nests (66%) failed in HTA. In 2004, 62.5% and 53.3% of all monitored nests were unsuccessful on HTA and LSWA respectively. Nest predation was the primary cause of nest failure on both sites and in both years (Table 11). I was unable to determine the specific predator of 4 nests.

Nesting phenology was bimodal, with the first peak in laying initiation in May followed by a second peak in July (Fig. 7). The largest number of successful hatches occurred in June and steadily declined throughout the remainder of the nesting season (Fig. 7). The proportion of successful nests was similar between nests initiated on or before 31 May (50.0%, n = 20) and nests initiated 1 June or after (54.5%, n = 22). The proportion of total nesting attempts prior to 31 May (47.62%, n = 20) and after 1 June (52.38%, n = 22) were also similar. The average clutch size was 16.3 in May but declined to an average of 11.4 by August, with an overall average of 14.1 for the entire nesting season.

The first set of models considered nest success as a function of temporal variation within and across years, and as a function of sex of the incubating adult. The best approximating model included a year and area effect (Table 3). Daily survival rates (DSR) were higher on LSWA in both years, however the difference was small in 2004 (Table 12). The next best model included sex of incubating adult. Although male incubated nests were estimated to have a positive effect on DSR ($\beta = 0.276$, SE = 0.25, CL = -0.23, 0.78), the 95% confidence interval did not indicate a significant sex effect.

The second set of models considered daily survival as a function of microhabitat structure and composition within 4 m of the nest. The best approximating model was again the best model from the first set of candidate models with a year and area effect only (Table 3). The next best model included total canopy, which was estimated to have a positive but non-significant effect on nest success ($\beta = 0.122$, SE = 0.19, CL = -0.27, 0.51).

Adding the effects for landscape composition had no influence on nest success (Table 3). The best model from the first set of candidate models again received the most support. The percent of roadside habitat within 210 m of the nest site was the only other covariate that received substantial support and was included in the next best model. The parameter estimate for the percent roadside habitat effect was 0.25 (SE = 0.22, CL = -0.19, 0.68). Distance metrics (e.g., distance from a nest site to the nearest grassland patch) were highly correlated with percent habitat type and therefore were not included in the landscape composition model (Set 3) analyses.

The best model estimating the effects of predator movement and foraging activities (i.e., landscape configuration) again included only a year and area effect (Table 3). The next best model included the covariate, distance from a nest site to the nearest grassland patch, and was estimated to have a negative but non-significant relationship with DSR (β = -0.25, SE=0.20, 95% CL = -0.63,0.14).

The basic (Set 1) model (area x year) received the most support when comparing the best 8 models (best 2 competing models from model sets 1-4) from the previous analyses estimating temporal, microhabitat, landscape composition, and landscape configuration effects on nest success (Table 3). The landscape configuration, landscape composition, and temporal models that included an additional single covariate received substantial support with ΔAIC_c of < 1.0. However, this result is misleading because with the addition of only one parameter the ΔAIC_c must be ≤ 2. The non-significant parameter estimates associated with these covariates support the inference that these models did not provide a more parsimonious explanation of the results.

Adding the effects for management techniques applied on LSWA had no influence on nest success. The best model included a year effect only (Table 4).

DISCUSSION

My estimates of various parameters of the breeding cycle were similar to those reported in the literature. Laying initiation dates were bimodal, peaking in late May and July. Average clutch size over the entire nesting season was 14.1, similar to estimates of 13.7 in Illinois (Klimstra and Roseberry 1975) and 15.0 in southeastern Iowa (Klimstra 1950). Previous studies have reported 15–30% of all nests are incubated by males (Suchy and

Munkel 1993, Burger et al. 1995, Taylor et al. 1999*b*). On LSWA and HTA, males incubated 28% of all monitored nests. Nest density was highest in roadside habitats, similar to that observed in Illinois (Roseberry and Klimstra 1984). The adult survival rate of 0.45 (SE = 0.06, CL = 0.34, 0.57) during the period of 11 May to 30 September on LSWA and HTA is also similar to adult survival rates observed in previous studies (Roseberry and Klimstra 1984, Burger et al. 1995*b*, Puckett et al. 1995, Taylor et al. 1999*a*) which ranged from 26 to 60% during the breeding season.

Nest success differed among years and study areas and was higher on LSWA in both years. In 2003, nest success was 100% on LSWA, but should be considered an artifact of the very low sample size of only 5 monitored nests. The estimated nest success on HTA in 2003 was 33.05%, although sample sizes were again very small. Nest success estimates in 2004 were more reliable with estimates of 48.47% on LSWA and 43.03% on HTA. The overall average of 45.08% in 2004 was slightly above the range of 28.3 to 43.7% previously reported in Iowa, Illinois, and Missouri (Klimstra 1950, Klimstra and Roseberry 1975, Burger et al. 1995*a*). This may be because nest success in the Iowa and Illinois studies (Klimstra 1950, Klimstra and Roseberry 1975) was calculated for all nests, whereas I only used nests that reached incubation. Consequently, the success rates in my study may overestimate the true population parameter for nest success. Similarly, Burger et al. (1995*a*) included only nests that reached incubation and reported a nest success rate of 43.7%.

Microhabitat characteristics, landscape composition, and landscape configuration within 210 m of a nest, and applied management techniques on LSWA did not have a measurable effect on nest success. The average litter depth and the average amount of litter within 4 m of a nest were the only microhabitat characteristics that differed between study areas. However, there were no significant differences among microhabitat metrics between successful and unsuccessful nests. In contrast to the findings here, previous studies have found that nest sites with less litter, and taller vegetation had a greater probability of success (Taylor et al. 1999b). The average height of vegetation over nest sites (LSWA = 55.1 cm, HTA = 62.7 cm) was similar to that found by Klimstra and Roseberry (1975) and Taylor et al. (1999b). However, litter depth and percent litter coverage were higher on LSWA as were the nest success rates, in contradiction to Taylor et al. (1999*b*). The lack of the measurable effect of microhabitat characteristics on nest success and the similarity among averages in vegetation cover and structure used by bobwhite at nest sites suggest that, other than the necessary general nesting requirements of moderately dense stands of grass with a relatively open nature at ground level and minimum vegetation height of 30-45 cm tall (Guthery 2000), nest success is not dependent on microhabitat vegetation characteristics.

My study provided no evidence that landscape composition within 210 m of a nest site influenced nest success. However, LSWA had a greater proportion of grassland habitat within the entire study area (46.1%), than did HTA (19.2%). White et al. (2005) recommend that at least 30% of the habitat within a bobwhite's home range should be composed of grassland habitat. Distance to the nearest grassland patch from a nest site did not affect nest success on LSWA or HTA, however the average percentage of grassland habitat within 210 m of a nest on LSWA was 55.3% and 36.1% in the HTA, which exceeds the 30% threshold recommended by White et al. (2005). Additionally, Taylor et al. (1990*a*) reported that bobwhite avoided cropfields and preferred sites closer to grassland patches in regards to nest site selection. These results suggest that bobwhite may in fact make nest site selection choices for sites with adequate grassland, even though this may not ultimately affect success.

The percent of roadside and small grain structure habitat was significantly greater surrounding successful nests than unsuccessful, but did not differ between study areas. As grassland habitats decrease in size and number due to urbanization and modern farming practices, roadsides are becoming increasingly important nesting areas. In this study, as well as in previous studies, high densities of bobwhite nests were found in roadside habitats (Klimstra and Roseberry 1975), which is likely indicative of the lack of suitable nesting habitat available within agricultural landscapes.

Previous studies have reported higher nest mortality rates for nests in closer proximity to timber patches (Clark et al. 1999, Bergin et al. 2000). On LSWA, the distance from a timber patch to a successful nest was nearly twice the distance of an unsuccessful nest to a timber patch. Raccoons (*Procyon lotor)*, one of the primary bobwhite nest predators (Klimstra and Roseberry 1975), are consistently active near woody habitats, whereas striped skunks (*Mephitis mephitis*), another common nest predator, prefer to forage along edges surrounding grasslands (Kuehl and Clark 2002). Although the landscape metrics measured in this study provided no evidence supporting the effect of predators on nest success, Kuehl and Clark (2002) found distances to habitat edges, timber, and grassland blocks of habitat can affect travel and foraging activities of predators such as the striped skunk, raccoon, and the red fox (*Vulpes vulpes*). Population monitoring and surveying of predator communities in conjunction with nest survival studies on the landscape scale are needed to fully understand if and how predators affect bobwhite nest success.

I could not demonstrate that the management techniques applied on LSWA to increase local quail populations increased nest success. Strip disking and edge feathering techniques largely focus on enhancing the quality of brooding and escape cover, and therefore are less likely to affect nest success. Previous studies have found that vertical cover and canopy cover of grasses and forbs (Mankin and Warner 1992, Patterson and Best 1996), can affect depredation of grassland nests, therefore the frequency and placement of burned grassland patches can be important to nest success. Early successional habitat is maintained on LSWA with an aggressive prescribed burning regimen. This management technique does provide microhabitat characteristics described in the literature as quality bobwhite nesting habitat, however as microhabitat characteristics were not determined to affect nest success on LSWA and HTA the distance to a burned field was also not likely to affect nest success.

Although nest success rates were different among study areas and years, the difference was insignificant in 2004. Also, the best model estimating adult survival predicted constant survival (45%) across years and areas (Table 13). Guthery's (1997) usable space hypothesis states that habitat quality is binary in nature, either usable or unusable, and predicts individuals will have similar fitness among areas of usable space (Guthery 1997). Guthery (1997) defines usable space as an area associated with habitat compatible with the physical, behavioral, and physiological adaptations of bobwhite. This hypothesis also predicts that management practices aimed at increasing usable space should result in an increase in the mean abundance of bobwhite on a specific area that contains unusable space. In support of the usable space hypothesis, previous research has suggested that landscape composition is not a consistent predictor of bobwhite nest success (Burger et al. 1995*a*, Taylor et al. 1999*a*, Taylor et al. 1999*b*) largely due to the fact that few differences were found among breeding parameters between landscapes that differed in available grassland habitat by as much as 50%. In this study, landscape composition was different between areas, in that the availability of grassland on LSWA was more than twice that of HTA. The lack of differences in microhabitat and landscape characteristics surrounding successful and failed nests on LSWA and HTA, as well as the similar adult survival estimates between areas gives further support to the usable space hypothesis.

The aggressive management focused on increasing the local quail populations on LSWA did not greatly improve nest success compared to areas that were not managed for quail. The lack of measurable improvement of nest success on LSWA compared with success on HTA could be the result of habitat improvement techniques being added into areas that were already space-time saturated (i.e., areas are usable at all points in space and time). Unfortunately, this hypothesis could not be tested due to the lack of bobwhite abundance estimates prior to the implementation of the management techniques. HTA provides usable space for quail populations in very localized areas within a landscape matrix dominated by rowcrop agriculture. Bobwhite abundance on the two study areas was not estimated, however if the usable space hypothesis is truly applicable to our study areas, abundance is likely greater on LSWA than on HTA.

MANAGEMENT IMPLICATIONS

The utilization of prescribed burning, strip disking, and edge feathering are commonly thought to maintain or enhance bobwhite habitat and emphasis should remain on continuing to manage landscapes with these techniques to sustain the early successional habitat in the landscape. However, additional emphasis should be focused on management of habitat that will provide additional usable space for bobwhite. Increasing private landowner participation in habitat conservation programs such as the Wildlife Habitat Incentives Program and continuous CRP is essential to increasing land usable to bobwhite and therefore increasing bobwhite abundance. Further research investigating bobwhite nest success in relation to predator space use and predator-prey relationships among different landscape compositions and configurations could improve land managers' ability to create and maintain adequate cover in varied landscapes, and therefore a greater proportion of usable space.

ACKNOWLEDGEMENTS

The Iowa Cooperative Fish and Wildlife Research Unit and the IDNR provided funding for this research project. We thank the many people who provided field assistance (J. Chmielenski, E. Hall, A. Lange, M. McInroy, K. Wilcox, and B. Williams). We greatly appreciate the help and cooperation of the IDNR Wapello Unit staff and the participating landowners in VanBuren County. We are especially grateful to T. Bogenschutz and C. Steffen of the IDNR for their assistance and valuable advice. We also appreciate W. Clark and R. Koford for helpful review comments.

LITERATURE CITED

Bergin T. M., L. B. Best, K. E. Freemark, and K. J. Koehler. 2000. Effects of landscape structure on nest predation in roadsides of a Midwestern agroecosystem: a multiscale analysis. Landscape Ecology 15: 131-143.

Burger, Wes L. 2001. Quail management: issues, concerns, and solutions for public and private lands-a southeastern perspective. Pages 20-34 in S.J. DeMaso, W.P. Kuvlesky, Jr., F. Hernandez, and M.E. Berger, eds. Quail V: Proceedings of the Fifth National Quail symposium, Texas Parks and Wildlife Department, Austin, TX.

______. E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Transactions of the 55th North America Wildlife and Natural Resources Conference 74-83.

______. M.R. Ryan, T.V. Dailey, and E.W. Kurzejeski. 1995a. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59(3):417-426.

______. T.V. Dailey, E.W. Kurzejeski, and M.R. Ryan. 1995b. Survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59(2):401-410.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, NY.

Clark, W. R., R. A. Schmitz, and T. R. Bogenschutz. 1999. Site selection and nest success of ring-necked pheasants as a function of location in Iowa landscapes. Journal of Wildlife Management 63(3): 976-989.

Cody, R. P. and J. K. Smith. 1991. Applied statistics and the SAS Programming Language. Fourth edition. Prentice Hall, Upper Saddle River, NJ.

Daily, T., and T. Hutton. 2003. On the edge: a guide to managing land for bobwhite quail. Conservation Commission of the State of Missouri. Columbia, MO.

Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. Northwest Science. 33:43-64.

Dimmick et al. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina. 96pp.

Dinsmore, S.J., G.C. White, and F.L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83(12): 3476-3488.

Errington, P.L. 1941. An eight-winter study of central Iowa bob-whites. The Wilson Bulletin 53(2)85-102.

Fowler, J., L. Cohen, and P. Jarvis. 1998. Practical statistics for field biology. Second edition. John Wiley & Sons Ltd. Chichester, West Sussex.

Greenfield, K.C., M.J., Chamberlain, L.W. Burger, Jr, and E.W. Kurzejeski. 2003. Effects of burning and disking conservation reserve program fields in improve habitat quality for northern bobwhite (*Colinus virginianus*). American Midland Naturalist 149(2): 344-353.

Guthery, F.S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61(2): 291-301.

______. 2000. On Bobwhites. Texas A&M University Press. College Station, TX, USA.

______., M.C. Green, R.E. Masters, S.J. DeMaso, H.M. Wilson, and F.B. Steubing. 2001. Land cover and bobwhite abundance on Oklahoma farms and ranches. Journal of Wildlife Management. 65(4):838-848.

Hawkins, L. J. 2000. Northern bobwhite and vegetation responses to thinned and created openings in conservation reserve program (CRP) loblolly pine plantations. Unpublished master theses, Clemson University, Clemson, SC.

Hurst, G.A. 1970. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Proceedings of the Tall Timbers conference on ecological animal control by habitat management. 2: 173-183.

Klimstra, W.D. 1950. Bob-white quail nesting and production in southeastern Iowa. Iowa State College Journal of Science. 24:385-395.

______. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Kuehl, A. K. and W. R. Clark. 2002. Predator activity related to landscape features in northern Iowa. Journal of Wildlife Management 66(4): 1224-1234.

Leopold, A. 1933. Game Management. Charles Scribner's Sons. New York, NY.

______. 1936. Quail population studies in Iowa and Wisconsin. Ecology 17(4):680-681.

Mankin, P. C. and R. E. Warner. 1992. Vulnerability of ground nests to predation on an agricultural habitat island in east-central Illinois. American Midland Naturalist 128: 281-291.

Mayfield, H.R. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

McKee, G., M.R. Ryan, and L.M. Mechlin. 1998. Predicting greater prairie-chicken nest success from vegetation and landscape characteristics. Journal of Wildlife Management 62(1):314-321.

Olinde, M.W. 2000. Vegetation response to disking on a longleaf pine site in southeastern Louisiana. Pages 32-35 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail symposium. Tall Timbers Research Station, Tallahassee, FL.

Otis, D. L. 1998. Analysis of the influence of spatial pattern in habitat selection Studies. Journal of Agricultural, Biological, and Environmental Statistics 3(3):254-267.

Patterson, M.P. and L.B. Best. 1996. Bird abundance and nesting success in Iowa CRP fields: The importance of vegetation structure and composition. American Midland Naturalist 135(1): 153-167.

Pollock, K.H., S.R. Winterstein, and C.M Bunck. 1989. Survival analysis in telemetry studies: The staggered entry design. Journal of Wildlife Management 53(1): 7-15.

Puckett, K.M., W.E. Palmer, P.T. Bromley, J.R. Anderson, Jr., and T.L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: A management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505-515.

______. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Pages 26-31 *in* L.A. Brennan, W.E. Palmer, Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Quinn, G.P., and M.J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge, UK.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Roseberry, J.L., and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, IL, USA.

Sargeant, A.B., M.A. Sovada, and R.J. Greenwood. 1998. Interpreting evidence of depredation of duck nests in the prairie pothole region. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND and Ducks Unlimited, Inc., Memphis, TN.

SAS Institute. 2001. SAS online document, version8. SAS Institute, Cary, NC.

Schmitz, R. A. and W. R. Clark. 1999. Survival of ring-necked pheasant hens during spring in relation to landscape features. Journal of Wildlife Management 63(1): 147-154.

Schroeder, R.L. 1985. Habitat suitability index models: Northern bobwhite. U.S. Fish and Wildlife Service. Biol. Rep. 82(10.104). 32pp.

Staller, E. L., W. E. Palmer, and J. P. Carroll. 2002. Macrohabitat composition surrounding successful and depredated northern bobwhite nests. Proceedings of the National Quail Symposium 5:61-64.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles

Scribner's Sons, New York, New York, USA.

Suchy, W.J. and R.J. Munkel. 1993. Breeding strategies of the northern bobwhite in marginal habitat Pages 69-73 in K.E. Church and T.V. Dailey, eds. Quail III: national quail symposium. Kansas Department of Wildlife and Parks, Pratt.

Taylor, J.D., II. and L.W. Burger Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitat in Mississippi. Pages 7-15 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, JR., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Taylor, J.S., K.E. Church, D.H. Rusch, and J.R. Cary. 1999a. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 675-685.

______. 1999b. Microhabitat selection by nesting and brood rearing northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 686-694.

Truitt, V.L. and T.V. Dailey. 2000. Efficiency of bait trapping and night lighting for capturing northern bobwhites in Missouri. Pages 207-210 in L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

White, B., P. Graham, and R.A. Pierce. 2005. Missouri bobwhite quail habitat appraisal guide: Assessing your farm's potential for bobwhites. University of Missouri Extension, Columbia, MO.

White, G. C., and R. A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. Academic Press, San Diego, California.

Wiens, J.A. 1974. Habitat heterogeneity and avian community structure in North American grasslands. American Midland Naturalist. 91:195-213

Table 1. Classification and description of habitat types of LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

Habitat Type	Description
Cornfields	Cropfield planted to corn
Grassland	Conservation Reserve Program (CRP) lands Hayfields Idle[a] Waterway
Pasture	Any field that has been grazed for agricultural purposes within ≤2 years
Roadside	Adjacent land within ≤4 m of a blacktop or gravel road
Small Grain Structure	Cropfield planted to soybeans Cropfield planted to wheat Cropfield planted to oats Cropfield that has not been seeded to crop for ≤2 years Food Plots
Timber	Woody cover

[a]Land that has not been disturbed for ≥ 3 years and not enrolled in the CRP.

Table 2. List and description of covariates used to estimate nest success on the LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

Abbreviation	Description
4 Meter Buffer	
RP	Vertical obstruction reading (VOR)
Height	Height of vegetation directly over nest
TC	Average total canopy
Forb	Average percent forb
Grass	Average percent grass
Litter	Average percent litter
Litter Depth	Average litter depth
210 Meter Buffer	
PCorn	Percent Cornfield
PGrain	Percent Small Grain Structure
PGrass	Percent Grassland
PPast	Percent Pasture
PRoad	Percent Roadside
PTimber	Percent Timber
NPSize	Nest patch size
NPEdDen	Nest patch edge density (m/ha)
TotEdDen	Total edge density (m/ha)
DistGrass	Distance from nest to nearest grassland
DistCorn	Distance from nest to nearest cornfield
DistEF	Distance from nest to nearest edge feathered area
DistStrip	Distance from nest to nearest strip disk
Dist02Burn	Distance from nest to nearest patch burned in 2002
Dist03Burn	Distance from nest to nearest patch burned in 2003

Table 3. Model selection results for bobwhite nest survival on LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

Model	K[a]	AIC_c[b]	ΔAIC_c	ω_i[c]
Set 1: Basic				
S(area x year)	4	190.68	0.00	0.37
S(area x year + Sex)	5	191.41	0.73	0.26
S(..)	1	192.71	2.02	0.14
S(area)	2	192.84	2.16	0.34
S(year)	2	193.70	3.02	0.22
S(area + year)	4	196.07	5.38	0.03
Best model from Set 1 carried over to evaluate effects of microhabitat metrics.				
Set 2: Microhabitat				
S(area x year)	4	190.68	0.00	0.26
S(area x year + TC)	5	192.35	1.67	0.11
S(area x year + LD)	5	192.39	1.70	0.11
S(area x year + Forb)	5	192.56	1.89	0.10
S(area x year + Height)	5	192.59	1.91	0.38
S(area x year + RP)	5	192.59	1.91	0.38
S(area x year + Litter)	5	192.65	1.97	0.37
S(area x year + Grass)	5	192.71	2.03	0.36
S(area x year + Forb + Height + Litter + LD)	8	197.93	7.24	0.00
S(area x year + Forb + Height + Litter + LD + RP + TC + Grass)	11	202.67	11.98	0.00

[a]The number of parameters
[b]Akaike's Information Criterion corrected for small sample size
[c]Akaike's model weight

Table 3. continued

Model	K[a]	AIC_c[b]	ΔAIC_c	ω_i[c]
Best model from Set 1 carried over to evaluate effects of landscape metrics within 210 m of a nest.				
<u>Set 3: Landscape Composition</u>				
S(area x year)	4	190.68	0.00	0.26
S(area x year + PRoad)	5	191.39	0.71	0.19
S(area x year + PTimber)	5	192.27	1.58	0.12
S(area x year + PGrain)	5	192.28	1.59	0.12
S(area x year + PGrass)	5	192.53	1.84	0.11
S(area x year + PPast)	5	192.63	1.94	0.10
S(area x year + PCorn)	5	192.64	1.96	0.09
S(area x year + PRoad + PTimber + PPast + PGrain + PGrass)	9	199.09	8.41	0.00
S(area x year + PRoad + PTimber + PPast + PGrain + PGrass + PCorn)	10	201.06	10.37	0.00
Best model from Set 1 carried over to evaluate predator related effects.				
<u>Set 4: Landscape Configuration</u>				
S(area x year)	4	190.68	0.00	0.20
S(area x year + DistGrass)	5	191.34	0.66	0.14
S(area x year + NPEdDen)	5	192.17	1.48	0.09
S(area x year + PTimber)	5	192.27	1.58	0.09
S(area x year + TC)	5	192.35	1.67	0.09
S(area x year + DistCorn)	5	192.36	1.68	0.09
S(area x year + PGrass)	5	192.53	1.84	0.08
S(area x year + RP)	5	192.60	1.91	0.08
S(area x year + TotEdDen)	5	192.71	2.02	0.07
S(area x year + NPSize)	5	192.71	2.03	0.07
S(area x year + NPSize + NPEdEdn + TotEdDen + PTimber + DistGrass + TC + RP + DistCorn)	12	202.26	11.57	0.00

Table 3. continued

Model	K^a	$AIC_c{}^b$	ΔAIC_c	$\omega_i{}^c$
Best 2 models from Sets 1-4 to evaluate effects of temporal, microhabitat, landscape composition, and landscape configuration effects.				
S(area x year)	4	190.68	0.00	0.28
S(area x year + DistGrass)	5	191.34	0.66	0.20
S(area x year + PRoad)	5	191.39	0.71	0.19
S(area x year + Sex)	5	191.41	0.73	0.19
S(area x year + TC)	5	192.35	1.67	0.12
S(area x year + DistGrass + PRoad + Sex + TC)	8	196.35	5.66	0.02

Table 4. Model selection results for bobwhite nest survival pertaining to management techniques implemented on LSWA in southeastern Iowa, USA, 2003 and 2004.

Model	K[a]	AIC_c[b]	ΔAIC_c	ω_i[c]
S(year)	2	74.19	0.00	0.33
S(year + Near02Burn)	3	75.51	1.32	0.17
S(year + Near03Burn)	3	75.61	1.42	0.16
S(year + DistEF)	3	75.88	1.69	0.14
S(year + DistStrip)	3	76.09	1.91	0.13
S(.)	1	78.16	3.97	0.05
S(year + DistEF + DistStrip + Near03Burn + Near02Burn)	6	79.49	5.29	0.02

[a]The number of parameters
[b]Akaike's Information Criterion corrected for small sample size
[c]Akaike's model weight

Table 5. Vegetation means (SE) at nest sites in 2003 and 2004 on LSWA (n = 20) and HTA (n = 22) in southeastern Iowa, USA.

	LSWA		HTA		Areas Pooled		Fate and Area
	Success (n=12)	Failure (n=8)	Success (n=8)	Failure (n=14)	Success (n=20)	Failure (n=22)	Pooled (n=42)
Vegetation Characteristic							
Height (cm)	57.25(9.73)	51.86(10.81)	65.71(10.32)	61.21(9.28)	60.37(7.11)	57.82(7.00)	59.00(4.94)
VOR (cm)	60.50(7.72)	66.75(12.00)	69.00(10.97)	62.43(5.40)	63.90(6.27)	64.00(5.40)	63.95(4.06)
Litter Depth (mm)	38.81(7.74)	57.79(10.23)	28.45(3.35)	24.46(4.24)	34.66(4.88)	36.58(5.66)	35.67(3.72)
Percent Coverage							
Total	85.79(2.85)	84.38(5.48)	87.06(3.06)	84.09(2.12)	86.29(2.05)	84.19(2.32)	85.19(1.55)
Grass	67.91(5.00)	72.85(5.80)	77.32(2.89)	75.56(4.48)	71.67(3.33)	74.56(3.48)	73.19(2.39)
Forb	31.56(5.03)	40.03(4.73)	30.96(9.14)	19.57(4.52)	31.32(4.59)	27.01(3.92)	29.06(2.98)
Woody	10.48(5.67)	7.56(4.71)	11.22(4.29)	7.07(3.06)	10.79(3.61)	7.29(2.57)	9.11(2.23)
Litter	94.72(2.10)	98.33(1.11)	89.10(3.72)	92.26(2.27)	92.47(1.99)	94.47(1.61)	93.52(1.26)

Table 6. Significance levels from PROC GLM analysis of microhabitat vegetation characteristics at nest sites in LSWA (n=20) and HTA (n=22) in southeastern Iowa, USA, with treatment contrasts for study area (LSWA vs. HTA), fate (successful vs. failure), and year (2003 vs. 2004) effects.

	Area[a]	Fate[a]	Area*Fate[a]	Year[b]
Vegetation Characteristic[c]				
Vertical Obstruction	0.741	0.910	0.614	0.903
Height	0.243	0.540	0.938	0.042
Litter Depth	0.011	0.557	0.041	0.004
Percent Coverage[d]				
Total	0.932	0.591	0.475	0.674
Grass	0.264	0.663	0.609	0.929
Forb	0.112	0.750	0.096	0.610
Woody	0.883	0.369	0.677	0.537
Litter	0.027	0.191	0.800	0.090

[a]$F_{1,38}$ statistics
[b]$F_{1,40}$ statistics
[c]Log transformed for analysis.
[d]Arcsine transformed for analysis.

Table 7. Percent habitat type (SE) within 210 m of nest sites in 2003 and 2004 on LSWA (n = 20) and HTA (n = 22) in southeastern Iowa, USA.

	LSWA (n=20)	HTA (n=22)	Successful (n=20)	Failure (n=22)	Fate and Area Pooled (n=42)
Percent Habitat Type					
Cornfield	0.89(0.61)	17.92(4.32)	6.11(3.43)	13.17(3.84)	9.81(2.62)
Small Grain Structure	15.62(3.32)	13.30(3.45)	19.01(3.22)	10.22(3.29)	14.34(2.37)
Grass	55.30(5.24)	36.13(4.16)	51.39(4.62)	39.68(5.26)	45.22(3.61)
Pasture	13.96(4.63)	15.80(4.47)	9.70(3.52)	19.68(5.03)	14.84(3.17)
Roadside	1.63(0.28)	1.47(0.33)	1.99(0.33)	1.15(0.26)	1.54(0.21)
Timber	12.61(2.76)	15.39(2.65)	11.82(2.21)	16.11(3.01)	14.26(1.90)

Table 8. Significance levels from PROC GLM analysis of percent habitat type within 210 m of nest sites in LSWA (n=20) and HTA (n=22) in southeastern Iowa, USA, with treatment contrasts for study area (LSWA vs. HTA), fate (successful vs. failure), and year (2003 vs. 2004) effects.

	Area[a]	Fate[a]	Area*Fate[a]	Year[b]
Percent Habitat Type[c]				
Cornfield	0.002	0.535	0.851	0.582
Small Grain Structure	0.971	0.088	0.613	0.016
Grass	0.013	0.539	0.461	0.239
Pasture	0.946	0.125	0.385	0.940
Roadside	0.883	0.061	0.394	0.252
Timber	0.681	0.350	0.243	0.086

[a] $F_{1,38}$ statistics
[b] $F_{1,40}$ statistics
[c] Arcsine transformed for analysis.

Table 9. Mean (SE) distance (m) from a nest site to the nearest edge, habitat type, and nearest edge of a management technique within a 210 m buffer surrounding nest sites in 2003 and 2004 on LSWA (n = 20) and HTA (n = 22) in southeastern Iowa, USA.

	LSWA		HTA		Fate and Area
	Successful (n = 12)	Failure (n = 8)	Successful (n = 8)	Failure (n = 14)	Pooled (n = 42)
Cornfield[a]	---	186.15(15.70)	124.10(33.17)	104.58(24.37)	153.96(12.54)
Small Grain Structure	68.50(20.80)	127.81(29.06)	108.77(29.65)	133.82(20.91)	106.05(12.79)
Grassland	64.71(19.22)	62.76(22.74)	30.35(8.75)	62.01(9.75)	20.65(6.54)
Pasture	145.43(27.97)	134.80(36.81)	157.63(17.93)	104.94(24.37)	128.81(14.05)
Roadside	117.01(23.38)	124.16(31.07)	77.57(34.04)	132.62(25.60)	114.46(14.08)
Timber	104.60(18.42)	56.16(23.73)	60.83(18.73)	63.75(14.54)	73.42(9.37)
Nearest Edge	27.88(11.53)	38.97(25.21)	9.17(3.94)	21.16(7.13)	24.19(6.24)
Management Technique[b]					
Distance to Edge Feather	154.18(16.77)	107.52(30.74)	---	---	135.52(17.39)[c]
Distance to Strip Disc	174.99(18.93)	184.35(25.65)	---	---	178.74(14.92)[c]

[a]There were 0 cornfield habitat patches within the 210 m buffer surrounding successful nests on LSWA.
[b]Applies only to LSWA due to lack of management on HTA.
[c]n = 20

Table 10. Significance levels from PROC GLM analysis of landscape configuration within 210 m of nest sites in LSWA (n=20) and HTA (n=22) in southeastern Iowa, USA, with treatment contrasts for study area (LSWA vs. HTA), fate (successful vs. failure), and year (2003 vs. 2004) effects.

Landscape Characteristic	Area[a]	Fate[a]	Area*Fate[a]	Year[b]
Distance from nest[c]				
Grassland patch	0.813	0.197	0.333	0.230
Timber patch	0.594	0.182	0.058	0.182
Nearest Edge	0.765	0.634	0.941	0.541
Edge Density[c]				
Nest Patch	0.243	0.365	0.100	0.378
Total 210 m	0.206	0.574	0.672	0.391
Management Technique[cd]				
Distance to Edge Feather	---	0.225	---	0.664
Distance to Strip Disk	---	0.937	---	0.645

[a]$F_{1,38}$ statistics
[b]$F_{1,40}$ statistics
[c]Log transformed for analysis.
[d]$F_{1,17}$ statistics for general linear models used to contrast means between year and fate of nests.

Table 11. Suspected causes of nest failure in 2003 and 2004 on LSWA (n = 8) and HTA (n = 14) in southeastern, Iowa, USA.

	LSWA	HTA	Total
Striped Skunk (*Mephitis mephitis*)	1	1	2
Raccoon (*Procyon lotor*)	0	1	1
Red Fox (*Vulpes vulpes*)	1	3	4
Coyote (*Canis latrans*)	0	1	1
Unknown Mammal	2	0	2
Unknown Predator	2	2	4
Adult depredated away from nest	1	3	4
Human	0	2	2
Abandon	1	1	2

Table 12. Daily survival rates and nest success estimates for LSWA (n = 20) and HTA (n = 22) in southeastern Iowa, USA, in 2003 and 2004.

Site and Year	N	DSR	SE	95% CI LCL	95% CI UCL	Nest Success[a]	SE
2003 LSWA	5	1.000	0.000	0.99	1.00	100.00%	0.00
2004 LSWA	15	0.969	0.011	0.94	0.98	48.47%	0.13
2003 HTA	6	0.953	0.023	0.88	0.98	33.05%	0.18
2004 HTA	16	0.964	0.011	0.93	0.98	43.03%	0.11

[a]Nest success is computed as $(DSR)^{23}$

Table 13. Model selection results for adult bobwhite survival from 11 May to 30 September on LSWA (n = 48) and HTA (n = 42) in southeastern Iowa, USA, 2003 and 2004.

Model[a]	K[b]	AIC_c[c]	ΔAIC_c	ω_i[d]
Constant	1	301.02	0.00	0.45
Area	2	301.99	0.97	0.28
Year	2	302.99	1.97	0.17
Area x year	4	303.86	2.84	0.11

[a]Model analysis was conducted using the staggered entry Kaplan-Meier estimator (Pollock et al. 1989) in Program Mark.
[b]The number of parameters
[c]Akaike's Information Criterion corrected for small sample size
[d]Akaike's model weight

FIGURE LEGENDS

FIGURE 1. Mean vegetation composition (+SE) at failed (n=22) and successful (n=20) nest sites on the HTA and LSWA in southeastern Iowa, USA, 2003 and 2004.

FIGURE 2. Mean vegetation structure (+SE) at failed (n=22) and successful (n=20) nest sites on HTA and LSWA in southeastern Iowa, USA, 2003 and 2004.

FIGURE 3. Percent of habitat types in LSWA and HTA in southeastern Iowa, USA, 2004.

FIGURE 4. Mean percent of habitat type within a 210 m buffer (+SE) surrounding successful (n = 20) and failed (n = 22) nests on LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

FIGURE 5. Mean Distance (m) from nest site to nearest habitat type within 210 m (+SE) for failed (n = 22) and successful (n = 20) nests on LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

FIGURE 6. Percent of nests per habitat type on LSWA (n = 20) and HTA (n = 22) in southeastern Iowa, USA, 2003 and 2004.

FIGURE 7. Date of laying initiation (n = 41) and successful hatch (n = 20) on LSWA and HTA in 2003 and 2004 in southeastern Iowa, USA.

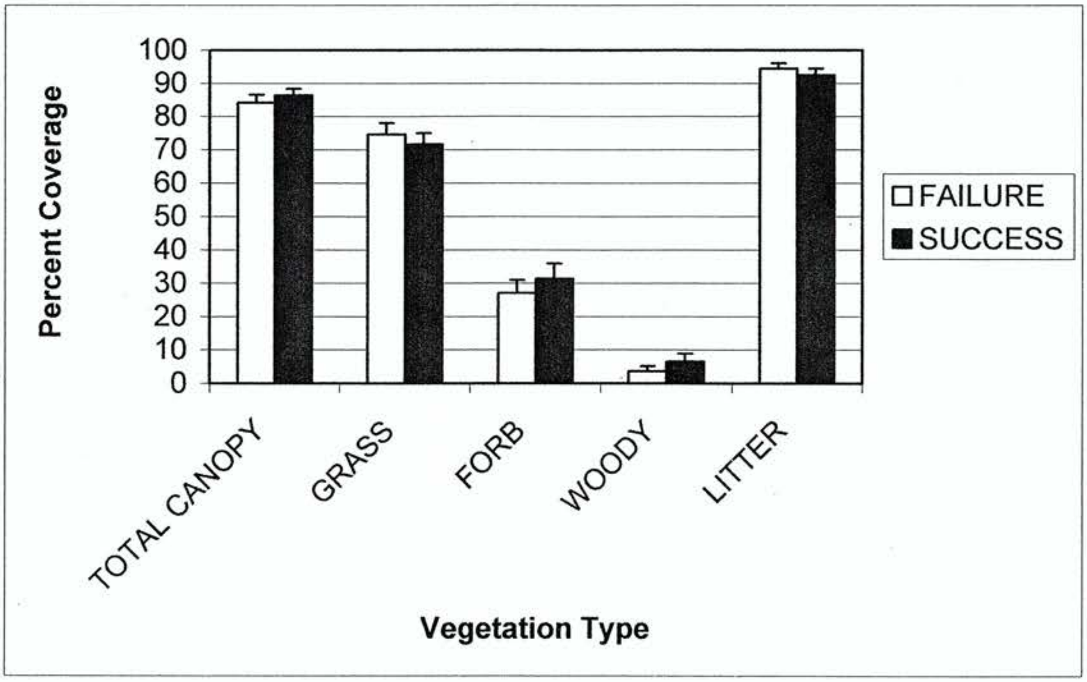

FIGURE 1.

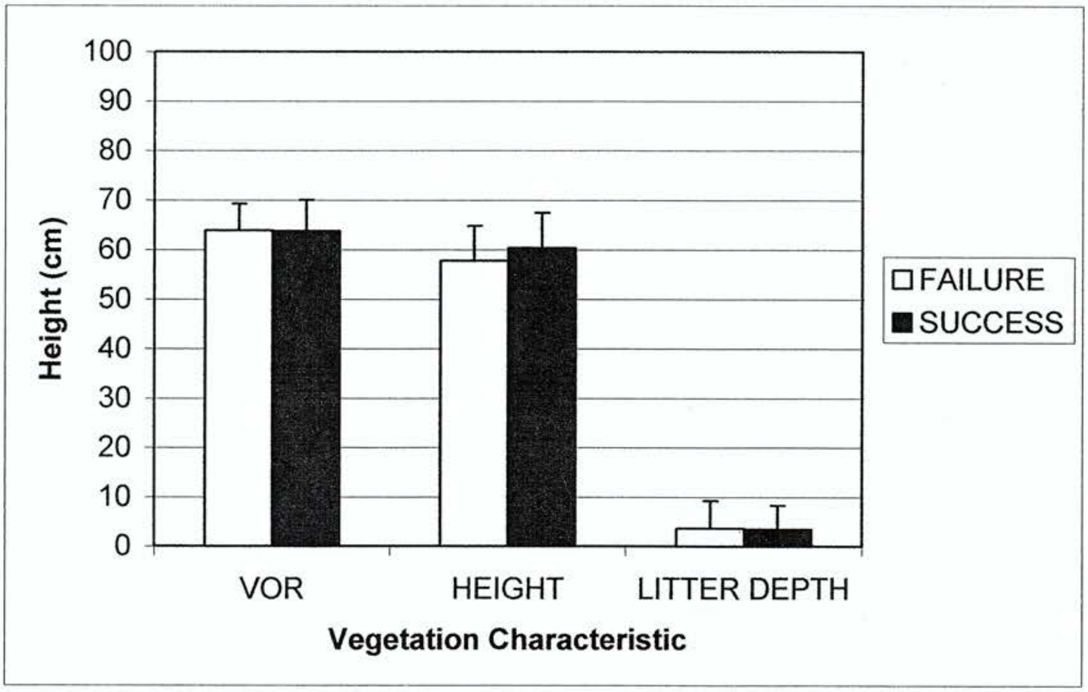

FIGURE 2.

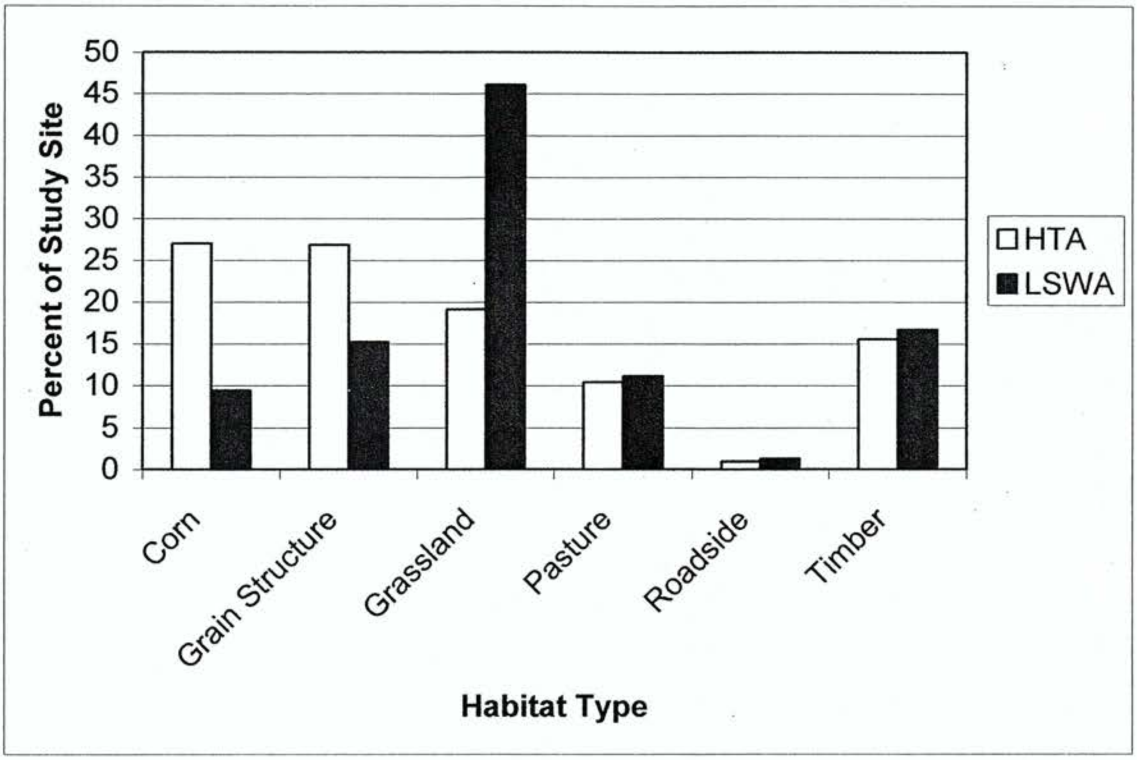

FIGURE 3.

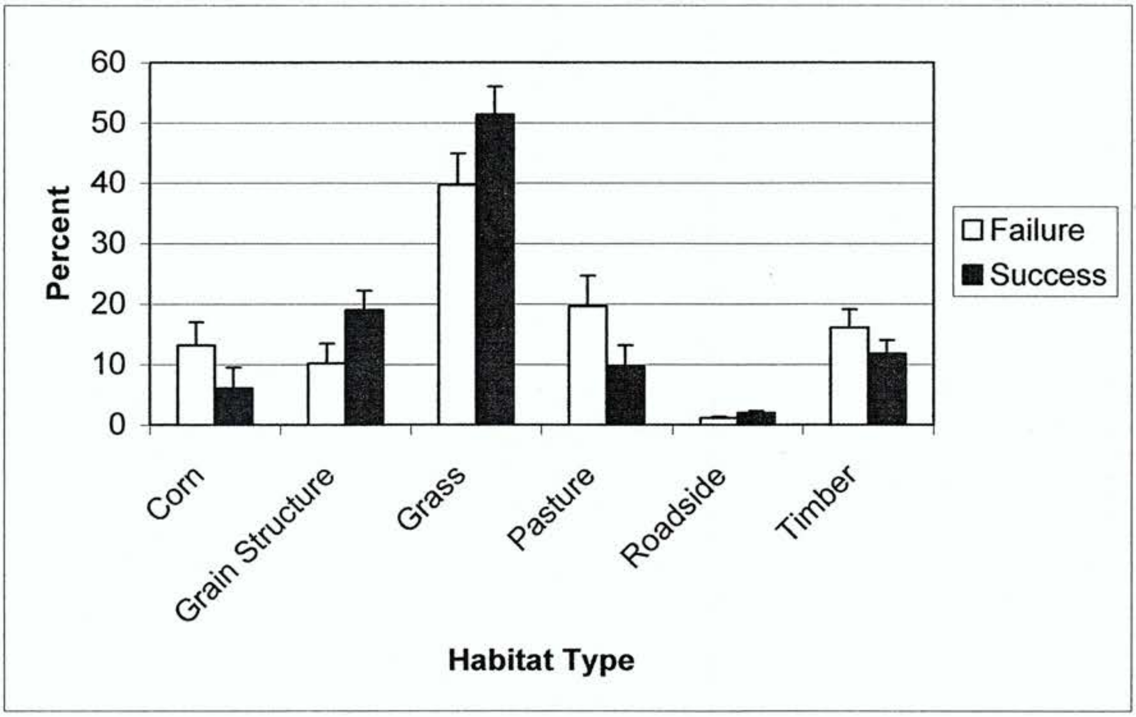

FIGURE 4.

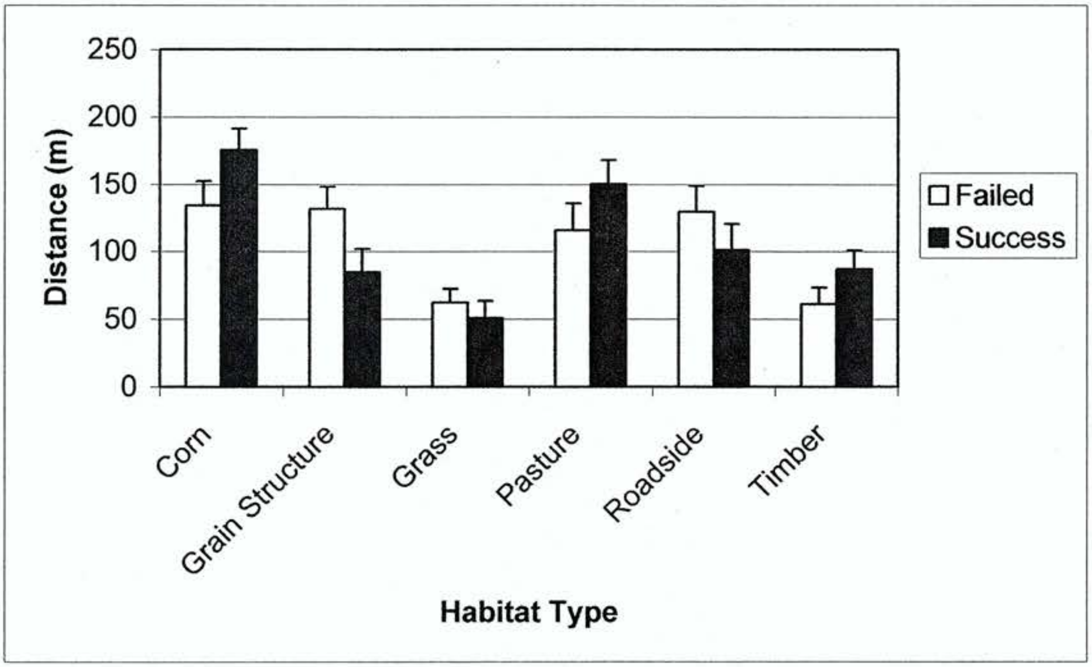

FIGURE 5.

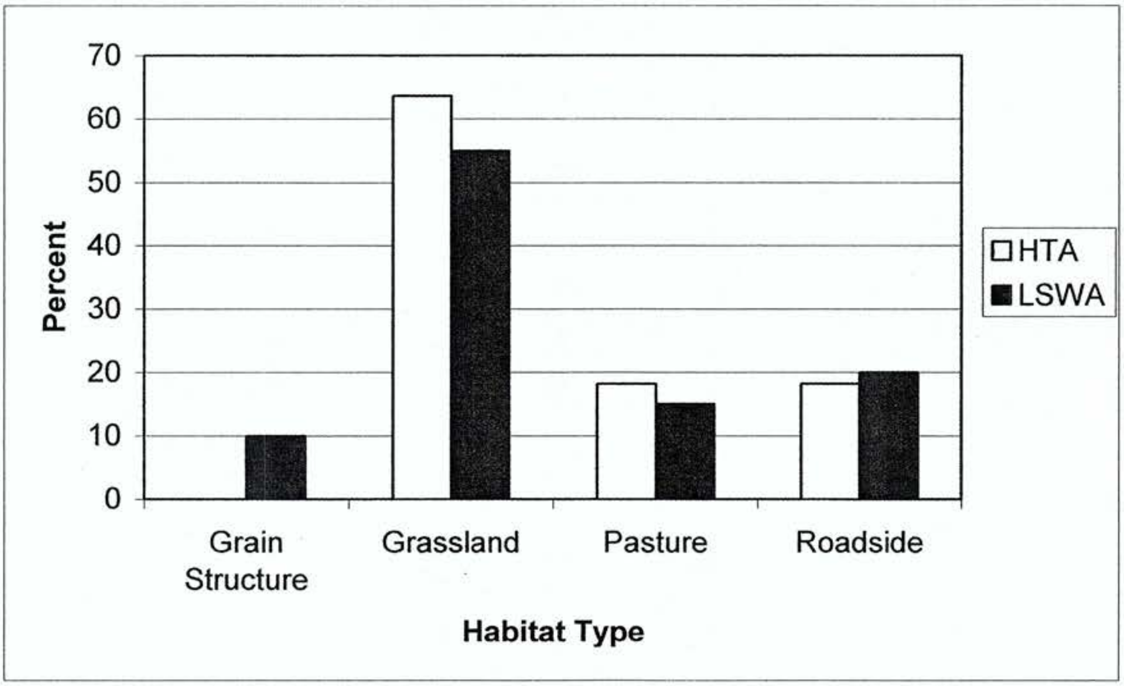

FIGURE 6.

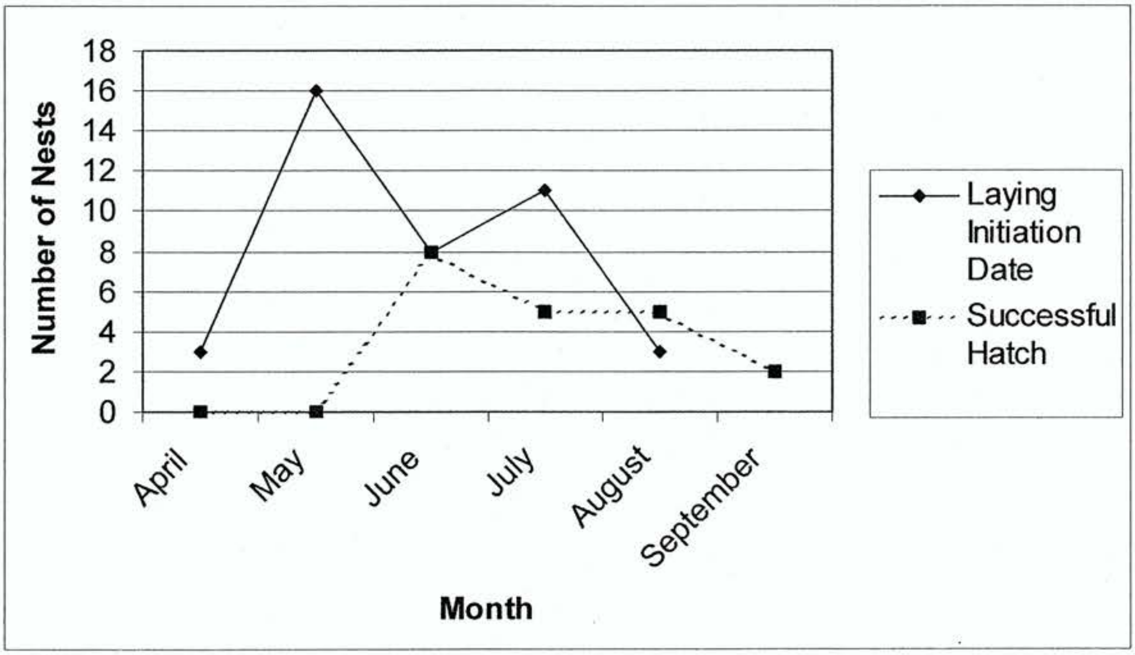
Number of Nests
18
16
14
12
10
8
6
4
2
0
April
May
June
July
August
September
Month
Laying Initiation Date
Successful Hatch

FIGURE 7.

CHAPTER 3. NOTHERN BOBWHITE BROOD HABITAT SELECTION IN RELATION TO LANDSCAPE SPATIAL PATTERNS AND HABITAT COMPOSTION

Lisa M. Potter and David L. Otis

ABSTRACT

The northern bobwhite (*Colinus virginianus)* is one of the most popular upland games species in North America, and in turn has been a focus of game management and research from as early as the 1920s. However, bobwhite populations continue to decline throughout their geographic range. The cumulative effects of advanced succession and monoculture farming are often cited as a primary cause of rangewide declines. As productivity may be one of the most important factors associated with changes in population size, identifying and managing quality nesting and brood habitats is vital to reversing the steady downward trend in bobwhite populations. In 2003 and 2004, we compared brood habitat selection of bobwhite in 2 landscapes in southeastern Iowa. The first was a 1452 ha state wildlife management area (managed) that since 1997 has been subjected to several management practices thought to promote quail recruitment. The second was a nearby township (2350 ha) used primarily for private agriculture production (private). At both the home range and patch scale, broods on the managed and private study areas used habitat types differently. At the home range scale, broods on the private area simply selected for all habitat types not in rowcrop production, while broods on the managed area selected for habitats with early successional habitat characteristics. At the patch scale, broods 2-weeks of age on the managed area selected for early successional habitats over all other habitats except roadsides, and showed an avoidance of timber patches. At 4 weeks of age, broods showed only an avoidance of timber patches. The percent of forb canopy cover within a habitat patch was a

significant predictor of brood patch use on the managed area, as were fields burned the previous year. There was no statistical evidence for brood habitat selection at the patch scale on the private study area. Chick survival estimates that are adjusted for high rates of brood amalgamation should be used to further investigate the relationship between brood habitat selection and fitness.

***Key Words*:** broods, chick survival, habitat management, habitat selection, Iowa, landscape, northern bobwhite, patch, prescribed burning, scale, strip disking

INTRODUCTION

Habitat use by northern bobwhite (*Colinus virginianus*) broods is one of the most understudied components of bobwhite ecology (Roseberry and Klimstra 1984). The lack of technical tools, such as long duration radio transmitters of sufficiently small size and weight, is often cited as the reason for the paucity of information (Taylor and Burger 2000). Previous investigators have reported that a major portion of the variance in spring to fall population change was due to differences in the number of chicks produced per hen; this ratio was the reproductive index most closely associated with recruitment into fall populations (Klimstra and Roseberry 1975, Roseberry and Klimstra 1984). As productivity may be one of the most important factors associated with changes in population size (Klimstra and Roseberry 1975, 1984, Burger et al. 1995, Taylor et al. 1999*a*, Taylor et al. 1999*b*), identifying and managing quality nesting and brood habitats is vital to reversing the steady downward trend in bobwhite populations (Dimmick et al. 2002). The cumulative effects of advanced succession and monoculture farming are thought be the primary cause of bobwhite declines (Burger 2001).

In response to the range wide declining population trend, the Southeast Quail Study Group Technical Committee recently initiated the Northern Bobwhite Conservation Initiative

(NBCI), which is a nationwide habitat goal oriented plan to restore bobwhite populations to densities estimated during the baseline year of 1980 (Dimmick et al. 2002). The plan sets out specific habitat management goals for the 15 Bird Conservation Regions that constitute the bobwhite geographic range. Through the implementation of improved habitat management practices and with the cooperation of federal, state, and private wildlife organizations, the NBCI predicts bobwhite decline could be halted by 2007 (Dimmick et al. 2002). The goals set for increasing bobwhite populations in Iowa and surrounding states focus on management and maintenance activities that will develop quality nesting, brood rearing, roosting and woody cover habitat. Early successional maintenance of Conservation Reserve Program (CRP) land, such as controlled burning and disking, the creation of field borders and hedgerows, and the conversion of cool season grasses, primarily fescue (*Festuca spp.*), to native grasses and forbs are a few of the management techniques suggested by the NBCI.

Although studies on habitat selection for brood rearing are few in number, important habitat requirements are thought to be vegetation stands dominated by legumes and forbs, 25-50% bare ground, and >50% overhead cover (DeVos and Mueller 1993, Taylor et al. 1999*b*, Puckett et al. 2000, Taylor and Burger 2000, Greenfield et al. 2003). It is generally agreed that quality brood rearing habitat is directly dependent on invertebrate abundance (Madison et al. 1995, Taylor et al. 1999*b*, Taylor and Burger 2000, Palmer et al. 2001, White et al. 2005). Strip disking and prescribed burning are common methods utilized to create vegetation composition and structure that promote high invertebrate abundance and allow young chicks to forage unimpeded. Although studies have identified a positive relationship between the quantity of available invertebrates and chick survival (Stoddard 1931, Burger et al. 1993, Palmer et al. 2001) few survival estimates during the brood rearing period are available (Suchy and Munkel 2000). Additionally, land managers rarely have the available resources to evaluate bobwhite population densities before and after the implementation of management techniques, therefore losing the potential to directly couple local landscape changes with changes in population densities. Without information regarding how and at what spatial scale habitat management positively affects bobwhite in localized areas, the means to increase rangewide populations will remain elusive.

The goal of my study was to estimate and compare brood habitat selection and chick survival rates as a function of habitat composition and structure and between managed and unmanaged landscapes. The information gained from this study will help managers to evaluate the influence of landscape composition and applied habitat management techniques on brood rearing. Specifically, my objectives were: 1) describe the vegetation characteristics at brood locations and compare vegetation characteristics in available and used habitat patches, 2) examine brood habitat selection as a function of habitat type and composition, brood age, and applied management techniques, and 3) compare chick survival rates between managed and unmanaged landscapes.

METHODS

Study Areas

The project was conducted from February – October 2003 and 2004 on the Lake Sugema Fish and Wildlife Area (LSWA) and selected areas within Harrisburg Township (HTA) in VanBuren County in southeastern Iowa. The study areas are located in the southern Iowa Drift Plain.

LSWA is a 1464 ha public wildlife area that is part of the Indian Creek-Van Buren Watershed Project sponsored by the Natural Resources Conservation Service (NRCS) and is managed by the Iowa Department of Natural Resources (IDNR). Land acquisition began in 1988 and was essentially completed by 1992. The majority of the cropland that was acquired was previously enrolled in CRP. In 1992, approximately 254 ha in the LSWA were flooded to provide fishing recreation. The remaining area consists of grassland, pasture, crop fields, and timber. Approximately 263 ha are leased out to private farmers and are primarily planted in wheat, soybean rotation, and hay. LSWA is open to hunting and fishing, with the exception of a 157 ha wildlife refuge area.

In 1997, the IDNR began an intensive bobwhite management regimen primarily designed to increase the local populations of northern bobwhites by providing bobwhite winter, nesting, and brooding habitats. Management techniques include strip disking/spraying (hereafter strip disk), prescribed burning, edge feathering of timber stands, and planting food plots. Timber edge feathering, prescribed burning, food plots, and strip disking are commonly used habitat modification methods for improving bobwhite habitat.

Spraying strips in grassland habitat with herbicides such as glyphosate (Roundup® or Roundup Ultra®) creates the same desired effects as mechanical strip disking (C. Steffen, pers. comm.). Both techniques result in the increase of the bare ground and forb component, an increase in invertebrate abundance, and a decrease in litter cover and litter depth; all of which provide foraging habitat and protective cover for chicks and adults during the breeding season (Greenfield et al. 2003). Approximately 23 ha of strip disks have been created in the LSWA. Strips were applied to the landscape at nonrandom lengths and at approximate widths of 10 to 18 m, with the majority (81%) 10 m wide. Strips were created utilizing both mechanical and chemical means on LSWA. All strips, regardless of technique or width, were combined for analyses.

Prescribed burning sets back the successional stage of an area while simultaneously increasing plant diversity and invertebrate abundance and decreasing litter cover and litter depth (Hurst 1970, Greenfield et al. 2003). At least one third of the 720 ha designated in the burning plan for LSWA are burned each year. The IDNR has applied edge feathering to approximately 34 km of timber edges. Edge feathering is created by cutting partway through trees along timber stand edges so the tops fall to the ground with sufficient connective material remaining to keep the tree alive. Edge feathered timber stands create living brush piles that provide year-round escape cover and loafing areas for bobwhite (Daily and Hutton 2003). The food plots on LSWA are planted to corn, sorghum, millet, wheat or soybeans, either planted as a single crop or in combinations, and are not controlled for weeds. Twenty-one food plots totaling 20 ha have been planted on LSWA.

LSWA is bordered along the northeast by the Shimek State Forest and the Lacey-Keosauqua State Park. The 360 ha Shimek State Forest is a managed multiple-use area for timber products, wildlife habitat, and recreation. The majority of the Lacey-Keosauqua State Park consists of timber habitat that is managed for recreation. The area immediately surrounding LSWA to the north, south and west is primarily devoted to private agricultural production. The majority of the cropland is either planted in corn and soybean rotation, or hay. The remaining land is primarily grazed or ungrazed pasture.

The second study area is a 2360 ha area in Harrisburg Township (HTA), located approximately 16 km northeast of the LSWA. This area is primarily devoted to the private agricultural production of corn and soybeans, planted in rotation, and hay. The remainder of the HTA consists of grazed pasture, land enrolled in CRP, and timber. The exact acreages and parcels used in the study area were dependent upon those landowners who granted permission to access their land. With the exception of 4 food plots planted by landowners, the HTA has not undergone any known habitat management for bobwhite populations.

Bobwhite Capture

Bobwhites were trapped continuously from 1 February to approximately 1 August in 2003 and 2004 using 3 trapping methods. In late winter and early spring, with the assistance of trained bird dogs, we extensively searched both study areas for bobwhite coveys. Behavioral signs such as roosting sites or bobwhite track marks were also used to locate bobwhite. We used walk-in funnel traps (Stoddard 1931:443) baited with cracked corn from 1 February to approximately 7 April in 2003 and 2004 to trap both males and females. In 2003, traps were placed non-randomly in brushy cover known or thought to be used by bobwhites. In 2004, to distribute the late winter and early spring trapping effort evenly and to facilitate the capture of a representative sample of the population, both study areas were divided into 12 sections approximately 197 ha each. Ten to 20 walk-in funnel traps were distributed throughout each section, localized in areas where scouting occasions indicated the presence of bobwhite in the immediate area. Each trap locale was pre-baited with cracked corn for a period of 4 days followed by 4 days of active trapping. One section at a time was actively trapped on each study area until trapping was attempted in all 12 sections on each area. In 2004, following the capture and the attachment of a radiocollar on 1 or more individuals from a covey, we used nightlighting techniques (Truitt and Dailey 2000) to attempt to capture the remaining individuals of that covey.

During the breeding season, cock-and-hen traps (Stoddard 1931:99) were used to capture males. Traps were placed non-randomly in locations where male bobwhite had been previously seen or heard. Electric callers, playing a loop-back tape of bobwhite assembly calls, were placed directly next to the trap to attract male bobwhites. Traps were checked 2-3 times daily, once at approximately 9 AM, again at midday if a bobwhite was seen around the trap during the morning check, and at sunset. The third trapping technique was targeted at females and involved nightlighting radiomarked males which were known to be paired with an unmarked female. In order to quickly identify the pairing of a radiomarked male with an unmarked female, weekly flushes of collared single males were conducted until the male was found with a radiomarked or unmarked female. The Universal Transverse Mercator (UTM) coordinates were recorded at each successful trap site.

Captured bobwhites were aged, sexed, weighed and marked with a unique #7 aluminum leg band. Each bobwhite weighing greater than 150 g was fitted with a 5.9 g, mortality sensing, pendant style necklace radio transmitter (Advanced Telemetry Systems, Isanti, MN) and released on-site if capture occurred before sunset. Bobwhites captured after sunset were held overnight and released at the trap site the following morning. All procedures were approved by the Iowa State University Committee on Animal Care.

Radio-Telemetry

Adult bobwhites were located 3-7 days per week from 1 April until 23 October 2003 and 27 October in 2004. The onset of incubation was suspected when an individual was found in the same location for 2 consecutive days during the breeding season. I monitored incubation status ≥5 times a week and returned to the nest once every 7 days in 2003 and once every 10 days in 2004 to monitor the status of the clutch.

Upon hatching of a successful nest, locations for brooding adults (hereafter brood location) were collected 7 days per week for a period of 28 days beginning the day after hatching. After 28 days, brood locations were collected 5 days per week until the adult was no longer associated with a brood or the formation of a covey with additional bobwhite occurred in late September or October. To obtain an estimate of chick survival, 3 flushing attempts were conducted within 3-5 days following the end of each 2 and 4-week interval. The largest number of flushed chicks observed out of the 3 flush attempts per interval was recorded as the number of surviving chicks. Brood flushes were not conducted during inclement weather or if surrounding vegetation was too damp. Occasionally, broods were flushed inadvertently during collection of daily telemetry locations and the number of chicks seen was recorded. I was not able to distinguish between brood abandonment, brood loss, or brood mixing (Faircloth et al. 2005).

For brood locations, I used the homing technique (White and Garrott 1990:42) to encircle the birds from a distance of 15-20 m. In 2003, after locating a brooding adult (hereafter brood), I recorded the bearing and distance from my location to the brood on a piece of flagging, which was then tied to nearby vegetation. Locations for each brood were also plotted on aerial photos of the study areas. I returned to the location of the flagging within 7 days and used the previously recorded bearing and distance estimates to collect the UTM coordinates at the actual location where the brood was previously found. Hand-held Garmin Etrex® and Etrex Venture® Global Positioning System (GPS) units were used to enable the transfer of information to a Geographical Information System (GIS) color infrared photograph of the study areas. In 2004, after locating a brood using the homing technique, I aligned myself in a cardinal direction to the brood from a distance of 15-20 m, and the UTM coordinates for the location of the brood were recorded by adding or subtracting the distance from the appropriate northing or easting UTM coordinate of my location.

To obtain a representative sample of diurnal habitat use by broods, each day was stratified into 3 blocked time segments. The first block of time began at sunrise and continued for 3 ½ hours. The third block of time began 3 ½ hours before sunset and concluded at sunset. The second time block covered the afternoon hours between the first and third time blocks (Hawkins 2000). I collected consecutive brood locations for each brood during different time blocks, as well as at different times within the specific blocks of time, resulting in at least 1 location within each time block every 7 days.

GIS Study Area Coverages

I used color infrared aerial photographs taken in 2002 to classify the study areas into habitat types. I hand-digitized to a minimum patch size of 0.01 ha and assigned habitat types to each study area and an approximate 1.6 km buffer surrounding each area using ArcView GIS 3.3. A habitat patch is defined as an area that consists of relatively homogenous vegetation that differs from its surroundings (Otis 1998). Study areas were classified into 6 habitat types (Table 1): a. Cornfields, b. Grassland, c. Pasture, d. Roadside, e. Small Grain Structure, f. Timber. Lakes on LSWA were excluded from the total available habitat, while farm ponds on LSWA and HTA were collapsed into the habitat category in which they were located. All habitat categories except crop fields were ground-truthed only in 2003 and crop fields were ground-truthed in both 2003 and 2004. On LSWA, I collected the UTM coordinates for all strip disks and areas of edge feathering.

Microhabitat Vegetation Measurement

In 2003, I measured total percent canopy coverage and relative percent canopy coverage, with overlapping percentages, of grasses, forbs, bare ground, litter, and woody vegetation <1 m in height within a 50- x 50 cm sampling frame (modified from Daubenmire 1959) centered around each brood location identified during the first 28 days of age. I also collected a litter depth measurement at the center of the sampling frame, as well as the dominant vegetation *genus* within the sampling frame. A visual obstruction pole (Robel et al. 1970) was placed in the center of the sampling frame and measured the visual obstruction reading (VOR) of vegetation from 4 m in each cardinal direction. All canopy coverage measurements were repeated at 2 and 4 m in each cardinal direction. Litter depth measurements were repeated along the same transects at 1, 2, 3, and 4 m.

In 2004, each daily brood location collected during the first 2-week interval was buffered with a 210 m radius circle using ArcView GIS 3.3. The buffered distance is the diameter of a 12 ha circle, which is an estimate of the area used by bobwhite during laying and incubation (Taylor et al. 1999*a*). I assumed the adult's knowledge of habitat during laying and incubation (23 days) may influence habitat use of brooding adults (Burger et al. 1995, Riley et al. 1998). The 14, daily 12 ha brood location buffers were merged into 1 polygon (hereafter available habitat polygon) to form the habitat designated as available to the adult bobwhite and its brood during the 2-week stage (Fig. 1). Each habitat patch within the available habitat polygon was hand digitized and assigned to a habitat type.

Sampling locations were randomly placed within each habitat patch ≥ 0.4 ha in the available habitat polygon using the DNR Random Sampling Tools extension (Minnesota Department of Natural Resources) for ArcView GIS 3.3. Three random points were created in patches ranging from 0.4–8 ha, and 5 random points were created in patches ranging from 8.1-24 ha in size. All crop fields, regardless of size, received only 3 random points due to the homogeneous vegetation composition and structure of agricultural crop fields. Final habitat types (Table 1) were not created until after the collection of all vegetation measurements in 2004. As a result, the final number of random sampling points per habitat patch ranged from 3-33 ($\bar{x} = 5$). For example, during the vegetation measurement field collection period, adjacent idle grassland and waterway patches each received 3 random sampling points, however the 2 adjacent patches were later condensed for analyses into 1 grassland patch containing 6 sampling points.

At each random sampling point, for all habitat types except timber, I measured the same vegetation canopy coverage metrics as 2003 within a 50- x 50 cm sampling frame (modified from Daubenmire 1959) centered around the random UTM coordinate. I also collected a litter depth measurement at the center of the sampling frame. All canopy coverage and litter depth measurements were repeated 2-4 m from the original random point by tossing the sampling frame in a random direction designated by twisting the dial of a compass. The vegetation measurements collected within the 2 sampling frames were pooled and treated as 1 sampling point. The creation of available habitat polygons and the vegetation sampling procedure were repeated at 28 days of age using brood locations collected during the third and fourth weeks after hatch (hereafter 4-week stage).

Random sampling points within timber patches were constrained to be within 50 m of a patch edge, because brood locations collected farther than 50 m into the interior of a timber patch were rare. Each random point was used as the center point of a 16 m transect aligned in a random direction determined by twisting the dial of a compass. At each transect, I measured the total percent canopy coverage and relative percent canopy coverage, with overlapping percentages, of grasses, forbs, woody vegetation <1 m in height, litter, bare ground and woody ground, within a 50- x 50 cm sampling frame (modified from Daubenmire 1959) at 4 m intervals for a total of 5 sampling points along each transect. The total percent canopy of vegetation 2-4 m in height (i.e. mid-story canopy), the density at breast height (dbh) of any tree $\geq$ 13 cm in diameter, and the total percent upper canopy, measured using a densitometer, were also measured within each sampling frame. Lastly, the number and dbh measurement for trees within 0.5 m of the transect were recorded.

Brooding Adult Home Range Estimates and Movements

Fifty and 95% home range estimates of brooding adults with ≥ 17 brood locations during the first 4 weeks after hatching were calculated using brood locations collected in 2003-2004 using the fixed kernel density estimator with least squares cross validation (Seaman et al. 1999, Powell 2000) in the Animal Movement extension (Hooge, Philip, Glacier Bay Field Station) for ArcView GIS 3.3. The Animal Movement extension was also used to calculate the average distance between consecutive brood locations as an index to brood movement rates. An inverse relationship between chick survival and brood movement has been documented for many gallinaceous species (Hill 1985, DeVos and Mueller 1993, Taylor and Guthery 2000).

Habitat Composition and Distance Metrics

To quantify the available brooding habitat composition, I calculated the percent of each habitat type within the available habitat polygons for each 2-week interval. White et al. (2005) suggest that approximately 40% of a bobwhite's home range should consist of brood habitat.

I used the Nearest Features (Jenness Enterprises) extension for ArcView GIS to calculate distances from the center of the 50% home range estimate to the nest site and to the nearest edge of strip disks and edge feathering sites. To calculate distances from each habitat patch edge within the available habitat polygon to the nearest edge of strip disks, edge feathering sites, and to fields burned in 2002, 2003, and 2004, I used the Identify Features Within a Distance (Jenness Enterprises) extension for ArcView GIS.

STATISTICAL ANALYSES

Microhabitat Vegetation Measurement

PROC UNIVARIATE and PROC MEANS (SAS Institute 2001) were used to obtain summary statistics including the mean, standard error, and standard deviation for all microhabitat metrics. All metrics were checked for collinearity using the Pearson correlation coefficient and were considered highly correlated when the Pearson correlation coefficient was ≥ 0.7 (Quinn and Keough 2002).

The means and standard errors of vegetation measurements collected in 2003 were used to describe microhabitat characteristics at brood locations. General linear models (PROC GLM; SAS Institute 2001) were used to test for differences in vegetation metrics at brood locations between study areas and habitat type. I was unable to test for differential area effects due to the low numbers of brood locations in cornfield habitats on LSWA and pasture habitats in HTA in 2003.

The means of the microhabitat measurements collected within habitat patches in 2004 were used in analyses to describe vegetation characteristics of used and unused patches within the 2 and 4-week available habitat polygons. A used patch is defined as a patch containing ≥ 1 brood location estimate. General linear models were used to compare differences in vegetation composition and structure between study areas, habitat type (excluding timber), brood use (used or not used), and brood age (2 or 4 weeks). I examined all possible 2-way interactions to test for differential study area, habitat type, brood use, and brood age effects.

Separate ANOVAs (PROC GLM) were conducted to compare 2004 vegetation composition and structure of timber patches between study areas (area), brood age (week), and brood use (status). I used area*status and area*week interactions to test for differential area effects.

In all GLM analyses, I treated the mean vegetation metrics as the response variables and the study area (LSWA or HTA), habitat type (Cornfield, Small Grain Structure, Grassland, Pasture, Roadside, or Timber), brood use (used or not used), and week (2 or 4 week) (i.e., brood age) as the categorical treatment factors. When a significant F-test ($P < 0.10$) for main effects or interactions was observed, differences among levels of that effect were tested with a Tukey-Kramer multiple comparison (SAS Institute 2001). Canopy coverage metrics were arcsine transformed, while litter depth, VOR, and dbh metrics were log transformed (Fowler et al. 1998) as needed to satisfy the normal distribution and equal variance assumptions of GLM. Untransformed means and errors are reported for ease of interpretation.

Brooding Adult Home Range Estimates and Movements

PROC UNIVARIATE and PROC MEANS (SAS Institute 2001) were used to obtain summary statistics including the mean, standard error, range, and standard deviation for the 95% and 50% home range estimates, brood travel distances, and the distance from the nest to the center of the 50% home range estimates. All metrics were checked for collinearity using the Pearson correlation coefficient and were considered highly correlated when the Pearson correlation coefficient was ≥ 0.7 (Quinn and Keough 2002).

I used general linear models (PROC GLM) to compare differences in brooding adult home range estimates, brood travel distances, and the distance from the nest site to the center of the 50% home range estimate between study areas and years. I treated the mean distance metrics as the response variables and the study area (LSWA or HTA) and year (2003 or 2004) as the treatment factors. A year*area interaction was used to test for differential year effects. Distance and home range estimates were log transformed as needed to improve normality and homogeneity of variances, however untransformed means and errors are reported for ease of interpretation.

Habitat Composition and Distance Metrics

To compare the proportion of used and available habitat types within brood available habitat polygons, the mean used and available proportions of each habitat type were used in analyses. For each habitat type, the area of all used patches within the available habitat polygon was summed to produce an overall use proportion. General linear models (PROC GLM) were used to compare differences in the proportion of available and used habitats between study areas and week (i.e., brood age). Differential area effects were tested with an area*week interaction. I treated the mean proportion of available and used habitat types as the response variables and study area and week as the explanatory variables. Metrics were arcsine transformed as needed to satisfy the normal distribution and equal variance assumptions of GLM. Untransformed means and errors are reported.

The distance from the nearest edge of a strip disk and edge feathering site to the center of the 50% brood home range estimate and the minimum distances from a patch edge to the nearest edge of a field burned in 2002, 2003, and 2004 were used in analyses to test whether the proximity to management techniques affected brood use (status). Habitat type*status interactions were used to test for differential habitat type effects. Distance metrics were treated as the response variables and habitat type and brood use were treated as the explanatory variables. All metrics were log transformed as needed to satisfy the normal distribution and equal variance assumptions of GLM. Untransformed means and errors are reported.

Habitat Selection

I used the Friedman test, which is a 2-way nonparametric analysis of variance based on ranks for a randomized complete block design, to test the hypotheses that all habitat types are used in proportion to their availability (Alldredge and Ratti 1986, 1992) at the second-order and third-order selection levels; i.e., there is no selection by broods for or against any habitat types at the home range or within the home range scale respectively. In the second-order selection analysis, or home range scale (Johnson 1980), I tested whether the proportion of each habitat type within the 2 and 4-week available habitat polygons (i.e., proportion used) was proportional to the total availability of each habitat type within the entire study area (Fig. 2). The area within the approximate 1.6 km buffer surrounding each study area was included into the total study area availabilities because all but five, 2 or 4-week available habitat polygons, were either partially (n = 19) or completely outside (n = 5) the original study area boundaries. The hypothesis that brood habitat use was proportional to habitat availability at the home range scale was tested using data accumulated during the first 2 weeks of brood rearing, and then tested again using data accumulated during the 4-week brood period. I treated broods as the blocks and habitat type as the treatment. I assumed that locations of one brood did not influence the locations of other broods (Alldredge and Ratti 1992). If the Friedman test statistic was rejected (i.e. each rank ordering of habitats for each brood is not equally likely), I used Fisher's least significant difference (LSD) procedure to estimate differences in relative use between all pairwise habitat type combinations (Conover 1980). Separate analyses were performed for each study area.

In the third-order selection analysis (Johnson 1980), or habitat use within the available habitat polygons, I tested whether brood use of each habitat type within the 2 and 4-week available habitat polygons was proportional to the availability of each habitat type within the respective available habitat polygons (Fig. 3). The proportion used of each habitat type was calculated by summing the number of brood locations within each habitat type and dividing by the total number of brood locations collected during the 2-week interval (i.e., number of brood locations per habitat type / total number of brood locations). Separate analyses were performed for each study area. The same assumptions and test procedures used in the second-order analyses were also used in the third-order analyses.

I developed negative binomial regression models (PROC NEGBIN; SAS Institute 2001) to predict the number of brood locations observed in a habitat patch, as a function of habitat type, brood age, microhabitat vegetation characteristics, and applied management techniques. The negative binomial model is a generalization of the Poisson model, and contains a parameter for overdispersion, which is a commonly encountered problem with Poisson count data (Allison 1999). Separate analyses were conducted for LSWA and HTA due to the differential brood location counts in habitat types on each area. For instance, pasture was not included in the LSWA analysis due to the rarity of available pasture within the available habitat polygons and in turn the lack of brood locations found in pasture habitats. The preliminary inclusion of cornfield in the HTA analysis led to significant overdispersion problems due to the rarity of brood locations within cornfield habitats during the 2-week interval and therefore was not included in the final analyses (Allison 1999). Timber was not included in either the LSWA or HTA analyses due to the lack of timber use by broods on both areas. Likelihood-ratio tests were used to test for significant ($P \leq 0.10$) individual coefficients (Allison 1999).

I developed two models to explore relationships in LSWA between brood use of patches and 1) habitat type and associated microhabitat characteristics, 2) brood age, and 3) applied management techniques including the presence or absence of strip disks within a habitat patch and the prescribed burn history of a patch. Microhabitat vegetation metrics (Table 2) were selected based upon their hypothesized influence on brood habitat selection reported in the literature, as well as my general knowledge of bobwhite ecology.

The first model (hereafter microhabitat model) considered variation in patch use with respect to brood age, habitat patch type, and microhabitat vegetation characteristics of habitats (Table 3). Broods have been reported to use a variety of habitat types including fallow fields, cereal and rowcrop, and CRP grasslands (DeVos et al. 1993, Taylor and Burger 2000). Previous investigators have shown that bobwhite select habitat patches based on ground cover components, but select sites within patches based on vegetation height and structure (Taylor 1999*b*). Vegetation providing at least 50% overhead cover with 25-50% bare ground has been suggested as quality brooding habitat (Taylor 1999*b*, Palmer et al. 2001, White et al. 2005). Hurst (1972) recommended that brood habitat should favor legumes and mixed forbs.

The second model (hereafter management model) considered the variation in brood use of patches on LSWA with respect to applied management techniques, habitat type, and brood age (Table 3). The use of prescribed burning and strip disking are considered beneficial to adult and juvenile bobwhite (Hurst 1970, Madison et al. 1995, Brennan et al. 2000*a*, Brennan et al. 2000*b*, Greenfield et al. 2003). An increase in invertebrate abundance has been associated with both strip disking and prescribed burning as a result of the increase in annual grasses and forbs which provide food resources for phytophagous insects (Hurst 1970, Manley et al. 1994). Bobwhite chicks' diets consist almost exclusively of small insects for at least the first 2 weeks of life (Stoddard 1931:160, Burger et al. 1993, Palmer et al. 2001). Invertebrates provide high concentrations of protein and energy to chicks and hens, and are considered critical to the growth and survival of chicks (Whitmore et al. 1986, Burger et al. 1993, Sotherton et al. 1993). It has been well documented that the first 2 weeks of life are the most critical for chick survival (Hurst 1972, Klimstra 1950, Whitmore et al. 1986, Devos et al. 1993). The management model was not applied to the brood use data on HTA because of the absence of habitat management.

RESULTS

We captured and radiotagged 53 (25 M, 28 F) bobwhite on LSWA and 51 (31 M, 20 F) on the HTA during 2003-04. The mean location estimate error was 8.50 m (SE = 1.17). On LSWA, there were 6 broods in 2003 and 4 broods in 2004; 8 of these were monitored for the entire 28 days. Six males and 4 females were found brooding chicks. One brood was found with only the nesting hen for 2 days after hatch, however the male from the original breeding pair returned and assisted with brooding thereafter. The male continued with the brooding responsibilities after the hen was depredated shortly after his return. On HTA, there were 2 broods in 2003 and 5 broods in 2004; 4 of these were monitored for the entire 28 days. Two males and 5 females were found brooding chicks. On LSWA, each brooding adult that was successfully flushed was found with an average of 9 chicks, similar to the average of 10 chicks seen with brooding adults during successful flushes on HTA.

Microhabitat Measurements

At 2003 brood locations, vegetation measurements differed between habitat types and study areas (Table 4). Percent litter and bare ground were significantly correlated (Pearson $\geq$ 0.7) and percent litter was subsequently excluded from analyses. Small grain structure had the highest percent coverage of forbs, however the percentage of bare ground was the lowest and the average litter depth was the second largest after roadsides (Table 5). Cornfields had the greatest percentage of bare ground and the lowest average litter depth and forb coverage (Table 5). Litter depth, percent bare ground and forb coverage were the only metrics to differ between study areas (Table 4) with less percent bare ground and greater litter depth on LSWA (Bare ground: LSWA $\bar{x}$ = 31.25, SE = 3.67, HTA $\bar{x}$ = 58.36, SE = 7.02; Litter depth: LSWA $\bar{x}$ = 8.01 mm, SE = 0.89; HTA $\bar{x}$ = 6.38 mm, SE = 1.65). Brood locations on LSWA had a greater percent coverage of forbs ($\bar{x}$ = 53.96, SE = 3.73) than HTA ($\bar{x}$ = 17.80, SE = 5.67).

Vegetation measurements collected in 2004 (Table 6) did not differ between study areas or weeks (i.e., brood age), but did differ between habitat types (Table 7 and 8). Percent grass and forb canopy coverage were significantly correlated (Pearson $\geq$ 0.7), as were percent litter and bare ground; percent grass and litter were subsequently excluded from analyses. Percent woody canopy was the only vegetation metric that did not differ between habitat types. The only vegetation metric that differed between used and unused habitat types (Table 7) was the total percent canopy coverage (p = 0.048). Total canopy coverage was also the only metric to have a significant habitat*status (i.e. habitat*brood use) interaction (p = 0.027). The average total percent canopy coverage was similar between used and unused patches of grassland (used: $\bar{x}$ = 87.66, SE = 1.67; unused: $\bar{x}$ = 86.24, SE = 1.85), pasture (used: $\bar{x}$ = 81.10, SE = 8.01; unused: $\bar{x}$ = 81.04, SE = 5.60), and roadside (used: $\bar{x}$ = 89.96, SE= 5.96; unused: ($\bar{x}$ = 86.25, SE = 2.67), although the total canopy coverage was significantly greater in used ($\bar{x}$ = 76.67, SE = n/a, n = 1) cornfield patches than in unused patches ($\bar{x}$ = 64.17, SE = 4.88, n = 3). However, the significant differences in total canopy coverage between used and unused patches should be viewed as an artifact of the sample size of only 1 brood on HTA in 2003.

Several vegetation metrics measured in timber patches were significantly correlated (Pearson $\geq$ 0.07) with greater than 1 variable; therefore only percent canopy of forbs, woody <1 m, mid- and upper-canopy, bare ground, litter depth and dbh were subsequently included in the analyses. The percent forb canopy coverage and the dbh were the only metrics to differ between study areas. LSWA timber patches (Table 8) had significantly greater ($p = 0.035$) percentages of forbs ($\bar{x} = 43.56$, SE = 4.25) than HTA timber patches ($\bar{x} = 28.93$, SE = 3.98) and smaller ($p = 0.076$) dbh measurements (LSWA: $\bar{x} = 10.18$, SE = 1.80; HTA: $\bar{x} = 20.99$, SE = 4.31).

Brooding Adult Home Range Estimates and Movements

The 50% brood home range estimate (Table 9) was significantly smaller ($p = 0.055$) on LSWA ($\bar{x} = 3.35$ ha, SE = 0.36, n = 8) than on HTA ($\bar{x} = 4.45$ ha, SE = 1.47, n = 4) however, there was a significant area*year interaction. Although the 50% home range estimate on HTA in 2003 ($\bar{x} = 7.96$ ha, SE = n/a, n = 1) was significantly greater than estimates on LSWA in both 2003 ($\bar{x} = 3.60$ ha, SE = 0.939, n = 3) and 2004 ($\bar{x} = 3.21$, SE = 0.30, n = 5), these results should be viewed as an artifact of the sample size of only 1 brood on HTA in 2003. The home range estimate on HTA in 2004 ($\bar{x} = 3.29$, SE = 1.27, n = 3) was similar to the LSWA 2003 and 2004 estimates. The 95% home range estimate also differed between areas ($p = 0.078$), but did not differ between years (Table 9). The home range estimate was again significantly larger on HTA ($\bar{x} = 36.96$ ha, SE = 9.96, n = 4) than on LSWA ($\bar{x} = 24.60$ ha, SE = 2.38, n = 8).

The average distance traveled between consecutive brood locations (Table 10) was 129.63 m (n=17) at 1-2 weeks of age and 151.54 m (n=12) at 3-4 weeks of age. The distance traveled at 1-2 weeks did not differ between areas or years (Table 11). Although there were no significant main effects between areas, there was a significant area*year interaction ($p = 0.077$) at 3-4 weeks of age. The average distance traveled between consecutive brood locations at 3-4 weeks was greater on HTA in 2003 ($\bar{x} = 266.90$ m, SE = n/a, n = 1; LSWA: $\bar{x} = 146.06$ m, SE = 31.42, n = 3) although, these results are again, likely an artifact of the sample size of only 1 brood on HTA in 2003. In 2004, the average distance traveled at 3-4 weeks was greater on LSWA ($\bar{x}$ = 145.50 m, SE = 22.04, n = 5), than on HTA ($\bar{x}$ = 128.64, SE = 26.05, n = 3). The average distance from a nest site to the center of the 50% home range estimate was 297.62 m (SE=56.61, n=12) and did not differ between areas or years (Table 11).

Habitat Composition and Distance Metrics

The proportion of all habitat types, except timber, in the available habitat polygons within the 2 and 4-week stage polygons differed between study areas (Table 12). Total area of polygons did not differ among areas or weeks. The average size of the 2 and 4-week stage polygons were 39.65 ha (SE=3.11) and 37.09 ha (SE=2.92) respectively. On LSWA, there were smaller proportions of available cornfield and pasture and greater proportions of small grain structure, grassland, and roadside than on HTA (Figure 4). Proportion used differed between sites only in small grain structure and pasture (Table 12). Use of pasture was greater on HTA (p = 0.084), while use of small grain structure was greater (p = 0.012) on LSWA (Figure 5). The proportion used of timber habitat was the only type to differ between brood ages, with use increasing at 3-4 weeks of age. On LSWA, there were no differences in brood patch use in relation to distances from a habitat patch to strip disks or edge feathering or to habitat patches that had been burned in 2002, 2003, or 2004. The average distance from a patch to the nearest strip disk, edge feathering, and patches burned in 2002, 2003, and 2004 was 256.05 m (SE = 28.26, n = 44), 150.53 m (SE = 14.76, n = 44), 64.84 m (SE = 17.19, n = 35), 263.70 m (SE = 34.13, n = 47) and 55.58 m (SE = 26.94, n = 11) respectively.

Habitat Selection

Friedman's Test-- On LSWA, the proportion of each habitat type within the 2 and 4-week stage available habitat polygons was different than would be expected if brood use were random within the entire study area (i.e., second order selection). Broods used small grain structure, grassland, and roadside habitat types more than cornfield, pasture, and timber habitats (Table 13). Cornfield and pasture habitats were consistently the type with the least proportion of use at each age. There was no significant difference in relative selection among small grain structure, grassland or roadside habitats. Conversely, at the 2-week stage on HTA, broods selected for grassland, pasture, and timber habitats relative to small grain structure and cornfield habitat types (Table 13). Grassland was the only type to be used more often than roadside habitats, whereas there were no significant differences in use between roadside and the remaining habitat types. There was only marginal statistical evidence ($p = 0.103$) to suggest the greater use of pasture habitats at the 4-week stage.

Within the available habitat polygons on LSWA (i.e., third order selection), broods from hatch to 14 days of age selected for small grain structure patches relative to all other habitat types except roadside patches, whereas roadside patches were used more than all habitats except small grain structure (Table 14). Timber patches received the least amount of use relative to all other habitat types ($p < 0.001$). From 3 to 4 weeks of age, all habitats were used significantly more than timber ($p=0.007$), while there were no significant differences in use between all other habitats. On HTA, there was no evidence of selection within the available habitat polygons at any brood age (Table 14).

Negative Binomial Regression-- The microhabitat model considered brood habitat selection in 2004 as a function of brood age, habitat type, and patch microhabitat vegetation characteristics. On LSWA, brood age, forb canopy cover, and the percent of bare ground were significant predictors of brood patch use (Table 15). The regression model predicted habitat patches with a greater percent of forb canopy and less bare ground coverage would have a greater number of brood locations, although the significance levels were marginal and the generalized coefficient of determination (R^2) was relatively low (R^2=0.29). Among all habitats, the largest difference in the percent of bare ground between used and unused patches was only 13%, however unused patches consistently had greater percentages of bare ground than used patches. Broods at 1-2 weeks of age were predicted to have 4.5 times more locations in a patch, but this may be an artifact of the greater number of brood locations collected during the 2-week stage versus the 4-week stage. Habitat patch types were not significant predictors of brood use on LSWA. On HTA, there were no variables that were significant predictors of brood use (Table 16) although the R^2 was low (R^2=0.11) suggesting no predictive power of the model. The management model considered brood use on LSWA as a function of brood age, habitat type, and the presence of management techniques. The only significant predictive variables were brood age and fields burned in 2003 (Table 17). The regression model predicted fields burned the previous year (i.e., 2003) would have approximately 8 times more brood locations.

DISCUSSION

Broods of gallinaceous species presumably increase movements in response to low densities of available food resources. The resultant increased potential for contact with predators is detrimental to chick survival due to the reported inverse relationship of survival and movement (Taylor et al. 2000). The average movement between consecutive brood locations was not significantly different between areas or brood age. Estimates of daily movements range from 277-589 m (Taylor and Guthery 1994, Taylor et al. 2000), but my estimates were much smaller, averaging only 129 m prefledge and 151 m postfledge. Taylor et al. (2000) also did not find differences in daily movements between prefledging and postfledging broods, although other studies have reported that daily movements significantly increase with brood age (Taylor and Guthery 1994). These discrepancies are likely a result of different methods used to estimate daily movements. For instance, previous studies have measured daily movements by collecting multiple location estimates per day, whereas I used the distance between consecutive daily locations as an index to brood movement rates.

The 50% home range estimates were similar between areas as were the 2004 distances from a nest to the center of the 50% home range estimates. Habitat types that fall within a 50% home range estimate are possibly more important to identifying quality brood habitat since the estimated range consists of areas in which broods are more likely to be concentrated. The similar 50% home range estimates and distances from a nest site to the center of the home range suggest that habitat and food resources within approximately 300 m of a nest were sufficient on both study areas to satisfy brooding requirements for at least 1-2 weeks after hatching. However, the 95% home range estimates were significantly larger on HTA, which could be an indication that resources are not as abundant on HTA resulting in the eventual necessity of increased movements by broods.

Previous research has reported that the highest rates of chick mortality occur during the first 2 weeks of life (Klimstra 1950, Hurst 1972, DeVos and Mueller 1993, Riley et al. 1998). Apparent chick survival rates in 2003 and 2004 were similar between LSWA (71.74%, n = 7) and HTA (67.42%, n =6), however brood amalgamation rates have been reported to be as high as 51.7% (Faircloth et al. 2005), and therefore our survival estimates are likely inflated. Additionally, the consistency of successfully flushing all chicks in a brood was low and in turn, the reliability of chick survival estimates obtained using the flushing method is also low. Greater reliability and precision in survival estimates are needed to test the hypothesis that chick survival is higher on LSWA as a result of a greater abundance of available resources. I was able to monitor twice as many broods for the entire 28-day period on LSWA than on HTA. Although the fate of chicks could not be determined following the predation of a brooding adult during the monitoring period, the greater number of broods monitored for the entire 28 days on LSWA may be an indication of higher chick survival given the assumption that chick survival decreases after the predation of the brooding adult.

The percent grass canopy and bare ground coverage at brood locations in 2003 were approximately 10-20% greater than previously reported estimates (Taylor et al. 1999*b*, Taylor and Burger 2000, Greenfield et al. 2003), while the average percent forb canopy of 43.33% was similar. Bare ground averaged 39.22% which falls within the recommended levels of 25-50% (White et al. 2005), and the average total percent canopy coverage of 77.35% is greater than the recommended minimum overhead cover of 50% (Palmer et al. 2001). The microhabitat vegetation characteristics that are used by broods on LSWA and HTA are similar to vegetation characteristics used by broods in different regions, specifically, Missouri and Kansas. Therefore, vegetation characteristics preferred by broods appear to be relatively constant.

Vegetation metrics in habitat patches in 2004 differed among habitat types. In comparison with vegetation measurements collected at 2003 brood locations, only small grain structure patches contained total canopy, forb coverage, and bare ground percentages most similar to those found at 2003 brood locations. Grassland, pasture, and roadside patches contained low forb and bare ground coverage. All 3 habitat types on both areas had less than 12% bare ground, which is well below the 25-50% recommend level (White et al. 2005), although all habitats had total canopies > 50%. Therefore, small grain structure patches on LSWA and HTA provide the vegetation composition and structure most similar to vegetation measurements collected at used brood locations and with brood habitat vegetation recommendations in the literature.

At the home range scale, broods on LSWA and HTA used available habitat types differently. At all ages, broods on LSWA selected for small grain structure, grassland, and roadside habitats relative to cornfield, pasture and timber habitats. However on HTA, broods at 2 weeks of age avoided small grain structure and cornfield habitat types relative to grassland, pasture, and timber habitats, whereas broods 4 weeks of age used only pasture habitats more frequently. The difference in the relative selection and avoidance of small grain structure habitats between LSWA and HTA could be an artifact of how habitat types were condensed into the final habitat categories used in the analyses. Habitat types were separated using vegetation structure, rather than composition. Small grain structures are similar to early successional habitats in that they have high percentages of forbs and bare ground. On LSWA, a large portion of the small grain structure patches were actually idle cropfields and no-till soybean fields, whereas on HTA, the largest proportion of small grain patches were conventionally planted soybean fields. Therefore, the small grain structure patches on LSWA were typically more diverse in both vegetation and invertebrate communities than the small grain structure patches on HTA and likely provided a greater abundance of available resources to young chicks. Given that the majority of the small grain structure patches in HTA were monotypic soybean fields and both small grain and cornfield habitats received the least amount of use relative to all other habitats, broods on HTA were simply avoiding cropfields at 2 weeks of age.

At the within home range scale, 2-week old broods on LSWA selected for small grain habitats over all other habitats except roadsides, and showed an avoidance of timber patches. Litter depth was relatively high and percent bare ground relatively low in timber patches, which could explain the avoidance behavior. Roadside habitats had very low bare ground percentages as well as a relatively low forb composition, however roadsides were still used more than would be expected if brood use was random. Due to the dissimilarity in vegetation characteristics between roadside and small grain vegetation and previously reported vegetation metrics, roadsides likely serve only as travel corridors.

At 4 weeks of age, broods on LSWA showed only an avoidance of timber patches. The difference in habitat selection between 2 and 4-week old chicks is likely due to the dependence on invertebrates for the first 2 weeks of life (Stoddard 1931, Burger et al. 1993, Palmer et al. 2001). Hill (1985) reported that a chick's diet changes with increasing age, gradually becoming more dependent on seed and plant material. Additionally, as chicks increase in size, the high percentages of bare ground become less important, as mobility and thermoregulation become less problematic (Rosene 1969). However, without chick survival rates that account for high rates of brood amalgamation, the relationship between habitat selection and survival will remain unknown.

Chick survival has been reported to be related to increased amounts of available invertebrates (Hill 1985, Sotherton 1993). Previous investigators have shown that invertebrate abundance and diversity vary greatly between habitat types (Whitmore et al. 1986, Burger et al. 1993), and that habitats dominated by forbs have a greater abundance of invertebrates (Hurst 1970, Manley et al. 1994). The microhabitat regression model predicted that on LSWA, patches with a greater percentage of forbs would contain a greater number of brood locations. Prescribed burning, strip disks, and filter strips have all been reported to be beneficial to broods due to the resulting increase in abundance of forbs, decrease in grass canopy, increase in bare ground, and an increase in plant species richness (Hurst 1972, Manley et al. 1994, Brennan et al. 2000a, Olinde 2000, Greenfield et al. 2003, Puckett et al. 2004,). Taylor and Burger (2000) found that breeding bobwhite consistently used burned and disked fields within their home ranges. The presence of strip disks within a patch on

LSWA did not prove to be a significant predictor of brood use. However, the management regression model predicted that a field burned the previous year would have 8 times as many brood locations. Both the microhabitat and management models indirectly support the evidence of the importance of invertebrates to bobwhite broods. Further research investigating invertebrate abundance within different habitat types will provide additional insight into the complex relationship between bobwhite broods and habitat selection.

There was no evidence on HTA for brood habitat selection at the within home range scale. Habitat composition within the 2 and 4-week available habitat polygons did not differ between weeks, however the percent available for each habitat type was different between areas. At the home range scale, broods on HTA simply selected for habitat that was not in agricultural crop production. The lack of selection at the within home range scale and the lack of microhabitat variables as significant predictors of brood use suggests that broods on HTA are selecting for habitat only at the home range scale and that patch use is random. Because vegetation metrics describing habitat types did not differ between areas, the lack of observed habitat selection on HTA cannot be attributed to dissimilarity in habitat type characteristics between areas, but rather the differences in habitat availability. In other words, if there are no patches available within brood home ranges on HTA that contain the characteristics that are preferable to broods, then habitat use is likely to be opportunistic. Broods will use areas that are simply within their awareness, regardless of quality.

MANAGEMENT IMPLICATIONS

Forb canopy coverage was the only vegetation characteristic that was a significant predictor of brood use, but is likely related more to invertebrate abundance than vegetation composition. Additionally, microhabitat vegetation characteristics did not differ between used and unused patches. This could be an indication that selection of brood habitat occurs at the spatial scale of the patch (Johnson 1980) rather than at a microhabitat scale. Managers should employ prescribed burning techniques within grasslands to maintain early successional vegetation characteristics, which in turn may attract breeding adults to the area. The enhancement of vegetation quality through these techniques will indirectly provide an increase in food resources for young chicks and hens, as well as provide screening cover from predators. Prescribed burning should only be carried out on small parcels of land at a time, as the burned area is unusable for a period of time following the burn. The presence of strip disks did not prove to be a significant predictor of brood use, however strip disking will result in vegetation characteristics that are similar to those created with prescribed burning. Therefore, disking should be used on areas that can either not be burned or on large parcels of land that must be burned in intervals. Implementing these procedures may prevent a patch from becoming an ecological sink. The effects of disking and burning are relatively short in duration and therefore should be carried out every 2-3 years to provide areas of quality brood habitat each season.

ACKNOWLEDGEMENTS

The Iowa Cooperate Fish and Wildlife Research Unit and the IDNR provided funding for this research project. We thank the many people who provided field assistance (J. Chmielenski, E. Hall, A. Lange, M. McInroy, K. Wilcox, and B. Williams). We greatly appreciate the help and cooperation of the IDNR Wapello Unit staff and the participating landowners in VanBuren County. We are especially grateful to T. Bogenschutz and C. Steffen of the IDNR for their assistance and valuable advice. We also appreciate W. Clark and R. Koford for helpful review comments.

LITERATURE CITED

Alldredge, J.R. and J.T. Ratti. 1986. Comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 50(1):157-165.

______. 1992. Further comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 56(1):1-9.

Allison, P.D. 1999. Logistic regression using the SAS system: Theory and application. SAS Institute Inc, Cary, NC.

Brennan, L.A., J.M. Lee, E.L. Staller, S.D. Wellendorf, and R.S. Fuller. 2000a. Effects of seasonal fire applications on northern bobwhite brood habitat and hunting success. Pages 66-69 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail symposium. Tall Timbers Research Station, Tallahassee, FL.

______. 2000b. Effects of disking versus feed patch management on northern bobwhite brood habitat and hunting success. Pages 59-62 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L Pruden, (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Burger, L.W. 2001. Quail management: issues, concerns, and solutions for public and private lands-a southeastern perspective. Pages 20-34 in S.J. DeMaso, W.P. Kuvlesky, Jr., F. Hernandez, and M.E. Berger, eds. Quail V: Proceedings of the Fifth National Quail symposium, Texas Parks and Wildlife Department, Austin, TX.

______., E.W. Kurzejeski, T.V. Dailey, and M.R. Ryan. 1993. Relative invertebrate abundance and biomass in conservation reserve program plantings in Missouri. Pages 102-108 *in* K.E. Church and T.V. Dailey, eds. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

______., M.R. Ryan, T.V. Dailey, and E.W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59(3):417-426.

Conover, W.J. 1980. Practical Nonparametric Statistics, 2ed. John Wiley & Sons. New York, NY.

Daily, T., and T. Hutton. 2003. On the edge: a guide to managing land for bobwhite quail. Conservation Commission of the State of Missouri. Columbia, MO.

Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. Northwest Science. 33:43-64.

DeVos, T. and B.S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Pages 83-90 *in* K.E. Church and T.V. Dailey, eds. Quail III: national quail symposium. Kansas Department of Wildlife and Parks, Pratt, KS.

Dimmick et al. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina. 96pp.

Faircloth, B.C., W.E. Palmer, and J.P. Carroll. 2005. Post-hatching brood amalgamation in northern bobwhites. Journal of Field Ornithology 76(2): 175-182.

Fowler, J., L. Cohen, and P. Jarvis. 1998. Practical statistics for field biology. Second edition. John Wiley & Sons Ltd. Chichester, West Sussex.

Greenfield, K.C., M.J., Chamberlain, L.W. Burger, Jr., and E.W. Kurzejeski. 2003. Effects of burning and disking conservation reserve program fields in improve habitat quality for northern bobwhite (Colinus virginianus). American Midland Naturalist 149(2): 344-353.

Hawkins, L. J. 2000. Northern bobwhite and vegetation responses to thinned and created openings in conservation reserve program (CRP) loblolly pine plantations. Unpublished master theses, Clemson University, Clemson, SC.

Hill, D.A. 1985. The feeding ecology and survival of pheasant chicks on arable farmland. Journal of Applied Ecology 22: 645-654.

Hurst, G.A. 1970. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Proceedings of the Tall Timbers conference on ecological animal control by habitat management. 2: 173-183.

______. 1972. Insects and bobwhite quail brood habitat management. Pages 65-82 *in* T.A. Morrison and J.C. Lewis, eds. Proceedings of the First National Bobwhite Quail Symposium. Oklahoma State University, Stillwater, OK.

Johnson, D.H. 1980. The comparison of usage and availability measurement for evaluating resource preference. Ecology 61:65-71.

Klimstra, W.D. 1950. Bob-white quail nesting and production in southeastern Iowa. Iowa State College Journal of Science. 24:385-395.

______. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Madison, L.A., T.G. Barnes, and J.D. Sole. 1995. Improving northern bobwhite brood rearing habitat in tall fescue dominated fields. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 49:525-536.

Manley, S.W., R.S. Fuller, J.M. Lee, and L.A. Brennan. 1994. Arthropod response to strip disking in old fields managed for northern bobwhites. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 48:227-235.

Olinde, M.W. 2000. Vegetation response to disking on a longleaf pine site in southeastern Louisiana. Pages 32-35 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail symposium. Tall Timbers Research Station, Tallahassee, FL.

Otis, D. L. 1998. Analysis of the Influence of Spatial Pattern in Habitat Selection Studies. Journal of Agricultural, Biological, and Environmental Statistics. 3(3)254-267.

Palmer, W.E., M.W. Lane, II, and P.T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65(4):861-870.

Powell, R.A. 2000. Animal home ranges and territories and home range estimators. Pages 65-110 *in* L. Boitani and T.K. Fuller, eds. Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York.

Puckett, K.M., W.E. Palmer, P.T. Bromley, J.R. Anderson, Jr., and T.L. Sharpe. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Pages 26-31 *in* L.A. Brennan, W.E. Palmer, Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Quinn, G.P., and M.J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge, UK.

Riley, T.Z., W.R. Clark, D.E. Ewing, and P.A. Vohs. 1998. Survival of ring-necked pheasant chicks during brood rearing. Journal of Wildlife Management 62(1):36-44.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range management. 23:295-297.

Roseberry, J.L., and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, IL, USA.

Rosene, W. 1969. The bobwhite quail: Its life and management. Rutgers University Press. New Brunswick, NJ.

SAS Institute. 2001. SAS online document, version8. SAS Institute, Cary, NC.

Seaman, D.E., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke, and R.A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63(2):739-747.

Sotherton, N.W., P.A. Robertson, and S.D. Dowell. 1993. Manipulating pesticide use to increase the production of wild game birds in Britain. Pages 92-101 *in* K.E. Church and T.V. Dailey, eds. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, New York, USA.

Suchy, W.J. and R.J. Munkel. 2000. Survival rates of northern bobwhite chicks in south-central Iowa. Pages 82-84 *in* L.Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Taylor, J.D., II. and L.W. Burger Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitat in Mississippi. Pages 7-15 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, JR., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Taylor, J.S. and F.S. Guthery. 1994. Daily movements of northern bobwhite broods in southern Texas. Wilson Bulletin 106(1):148-150.

______. 2000. Habitat and weather effects on northern bobwhite brood movements. Pages 153-157 *in* L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

Taylor, J.S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999a. Macrohabitat effects on Summer survival, movements, and clutch success of Northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 675-685.

______. 1999b. Microhabitat selection by nesting and brood rearing northern bobwhite in Kansas. Journal of Wildlife Management 63(2): 686-694.

Truitt, V.L. and T.V. Dailey. 2000. Efficiency of bait trapping and night lighting for capturing northern bobwhites in Missouri. Pages 207-210 in L.A. Brennan, W.E. Palmer, L.W. Burger, Jr., and T.L. Pruden (eds.). Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL.

White, B., P. Graham, and R.A. Pierce. 2005. Missouri bobwhite quail habitat appraisal guide: Assessing your farm's potential for bobwhites. University of Missouri Extension, Columbia, MO.

White, G. C., and R. A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. Academic Press, San Diego, California.

Whitmore, R.W., K.P. Pruess, and R.E. Gold. 1986. Insect food selection by 2-week-old ring-necked pheasant chicks. Journal of Wildlife Management 50(2):223-228.

Table 1. Classification and description of habitat types in LSWA and HTA in southeastern Iowa, USA, 2003 and 2004.

Habitat Type	Description
Cornfields	Cropfield planted to corn
Grassland	Conservation Reserve Program (CRP) lands Hayfields Idle[a] Waterway
Pasture	Any field that has been grazed for agricultural purposes within ≤2 years
Roadside	Adjacent land within ≤4 m of a blacktop or gravel road
Small Grain Structure	Cropfield planted to soybeans Cropfield planted to wheat Cropfield planted to oats Cropfield that has not been seeded to crop for ≤2 years Food Plots
Timber	Woody cover

[a] Land that has not been disturbed for ≥ 3 years and not enrolled in CRP.

Table 2. List and description of covariates used to predict the amount of habitat patch use by broods on the LSWA and HTA in southeastern Iowa, USA, 2004.

Abbreviation	Description
Habitat	Habitat type (Cornfield, Small Grain Structure, Grassland, Pasture, and Roadside)
Week	Brood Age (2 or 4 weeks)
RP	Vertical obstruction reading (VOR)
TC	Average total canopy
Forb	Average percent forb
Woody	Average percent woody cover $\leq$1m in height
BG	Average percent of bare ground
LD	Average litter depth
Strips	Presence of strip disks
02Burn	Field burned in 2002
03Burn	Field burned in 2003
04Burn	Field burned in 2004

Table 3. Negative binomial models predicting the amount of habitat patch use by broods in relation to brood age, habitat type, microhabitat vegetation characteristics, and habitat management techniques on LSWA and HTA in southeastern Iowa, USA, 2004.

Microhabitat $\log\lambda = \beta_0 + \text{Habitat}^{a} + \text{Week}^{b} + \text{RP} + \text{TC} + \text{Forb} + \text{Woody} + \text{BG} + \text{LD}$

Management[c] $\log\lambda = \beta_0 + \text{Habitat} + \text{Week}^{b} + \text{Strips} + \text{02Burn} + \text{03Burn} + \text{04Burn}$

[a]LSWA: Habitat includes Cornfield, Small Grain Structure, Grassland, and Roadside; HTA: Habitat includes Small Grain Structure, Grassland, Pasture, and Roadside.
[b]Week refers to age of brood (2 or 4 weeks)
[c]Management model applies only to LSWA.

Table 4. Significance levels from PROC GLM analysis of microhabitat vegetation characteristics in 2003 at brood locations in LSWA (n=60) and HTA (n=25), in southeastern Iowa, USA. Model factors were habitat type (cornfield vs. small grain structure vs. grassland vs. roadside) and study area (LSWA vs. HTA).

	Habitat Type[a]	Study Area[b]
Vegetation Structure[c]		
Vertical Obstruction (cm)	0.122	0.835
Litter Depth (mm)	<0.0001	0.001
Percent Coverage[d]		
Total	0.001	0.737
Grass	<0.0001	0.423
Forb	<0.0001	0.065
Woody	<0.0001	0.167
Bare Ground	<0.0001	0.003

[a]$F_{3,76}$ statistics.
[b]$F_{1,76}$ statistics.
[c]Log transformed for analysis.
[d]Arcsine transformed for analysis.

Table 5. Vegetation means (SE) at 2003 brood locations in LSWA and HTA (n=85) in southeastern, Iowa, USA. Dissimilar superscripts represent significant ($P < 0.10$) Tukey-Kramer comparisons.

	Cornfield[A]	Small Grain[B]	Grassland[B]	Roadside[B]	LSWA[C] (n = 60)	HTA[C] (n = 25)	Areas Pooled
Vegetation Structure							
VOR (cm)	89.82(9.19)	91.66(5.79)[a]	39.85(7.59)[a]	56.42(11.22)[a]	75.90(5.63)[c]	81.10(6.94)[c]	77.43(4.45)
Litter Depth (mm)	1.39(0.40)	10.02(1.03)[a]	4.50(1.95)[b]	11.45(2.29)[a]	8.01(0.89)[c]	6.38(1.65)[d]	7.53(0.79)
Percent Coverage							
Total	58.37(3.35)	81.66(2.34)[a]	80.65(2.05)[a]	75.39(3.35)[a]	81.22(1.84)[c]	68.07(3.18)[c]	77.35(1.72)
Grass	57.38(3.52)	30.61(4.10)[a]	76.83(1.51)[b]	52.30(4.59)[a]	45.46(4.00)[c]	52.04(4.44)[c]	47.40(3.12)
Forb	2.34(0.50)	65.31(3.82)[a]	25.25(4.95)[b]	28.76(9.18)[b]	53.96(3.73)[c]	17.80(5.67)[d]	43.33(3.58)
Woody	1.09(1.07)	2.46(1.01)[a]	0.91(0.81)[a]	22.38(6.17)[b]	1.93(0.74)[c]	7.30(2.69)[c]	3.51(0.97)
Bare Ground	86.74(2.15)	21.53(3.74)[a]	50.75(5.73)[b]	27.77(9.14)[a]	31.25(3.67)[c]	58.36(7.02)[d]	39.22(3.55)

[A]Tukey-Kramer multiple comparison tests not estimable due to the lack of 2003 brood locations in cornfield habitats on LSWA.
[B]Dissimilar superscripts represent significant ($P < 0.10$) Tukey-Kramer comparisons.
[C]Dissimilar superscripts represent significant ($P < 0.10$) Tukey-Kramer comparisons.

Table 6. Microhabitat vegetation means (SE) of used and unused patches in 2004 brood available habitat polygons in LSWA (n = 6) and HTA (n = 5) in southeastern Iowa, USA.

	Used		Not Used		Areas Pooled	
	LSWA (n = 29)	HTA (n = 13)	LSWA (n = 33)	HTA (n = 27)	Used (n = 42)	Not Used (n = 60)
Vegetation Structure						
VOR	59.60(4.59)	46.39(5.46)	48.72(4.83)	55.28(6.30)	55.51(3.68)	51.67(3.87)
Litter Depth	26.72(4.04)	19.47(3.22)	20.19(4.01)	21.61(3.84)	24.48(2.99)	20.83(2.78)
Percent Coverage						
Total Canopy	82.66(1.86)	79.08(4.03)	85.76(2.95)	80.98(2.78)	81.55(1.78)	83.46(2.04)
Grass	51.84(5.07)	52.90(9.12)	55.71(5.80)	54.76(5.21)	52.17(4.43)	55.25(3.88)
Forb	42.13(3.76)	42.75(4.42)	40.16(5.34)	36.51(5.11)	42.32(2.91)	38.40(3.68)
Woody	0.95(0.33)	0.53(0.29)	0.26(0.19)	1.22(0.68)	0.82(0.25)	0.71(0.34)
Bare Ground	16.76(3.89)	17.88(4.97)	23.83(4.37)	25.90(6.19)	17.11(3.06)	24.76(3.65)
Litter	83.17(3.91)	82.16(4.98)	76.18(4.38)	74.08(6.19)	82.86(3.08)	75.24(3.65)

Table 7. Significance levels from PROC GLM analysis of microhabitat vegetation characteristics within 2004 brood available habitat polygons in LSWA (n=6) and HTA (n=5) in southeastern Iowa, USA. Model factors were study area (LSWA vs. HTA), habitat type (cornfield vs. small grain structure vs. grassland vs. pasture vs. roadside), status (Used vs. Not Used), and week (2 and 4 weeks). Only factors with at least 1 significant difference are displayed in the table.

	Habitat[a]	Status[b]	Habitat*Status[c]	Week[b]
Vegetation Structure[d]				
VOR (cm)	<0.001	0.526	0.403	0.114
Litter Depth (mm)	<0.001	0.233	0.263	0.934
Percent Coverage[e]				
Total	0.078	0.048	0.027	0.655
Forb	0.001	0.807	0.648	0.913
Woody	0.407	0.617	0.840	0.545
Bare Ground	<0.001	0.456	0.801	0.715

[a]$F_{4,79}$ statistics.
[b]$F_{1,79}$ statistics.
[c]$F_{3,79}$ statistics.
[d]Log transformed for analysis.
[e]Arcsine transformed for analysis.

Table 8. Vegetation means (SE) for habitat types in brood available habitat polygons in LSWA and HTA in southeastern, Iowa, USA in 2004. Dissimilar superscripts represent significant ($P < 0.10$) Tukey-Kramer comparisons.

	Habitat Type					Timber	
	Cornfield (n=4)	Small Grain (n=36)	Grassland (n=44)	Pasture (n=8)	Roadside (n=10)	LSWA (n=20)	HTA (n=11)
Vegetation Structure							
VOR (cm)	132.91(11.99)[a]	51.83(4.57)[b]	52.67(2.74)[b]	35.95(7.09)[b]	42.90(5.61)[b]	---	---
Litter Depth (mm)	1.77(0.47)[a]	7.21(0.95)[b]	31.72(2.83)[c]	15.97(2.62)[cd]	48.71(7.70)[ce]	23.01(3.43)[a]	32.88(10.00)[a]
DBH (in)	---	---	---	---	---	10.18(1.80)[a]	20.99(4.31)[b]
Percent Coverage							
Total	67.29(4.66)[ab]	77.76(3.15)[a]	86.83(1.27)[a]	81.06(4.25)[a]	88.10(3.14)[ac]	74.40(3.87)[a]	82.33(3.32)[a]
Grass	67.29(4.66)[a]	27.23(5.43)[b]	67.05(2.17)[a]	64.33(6.39)[a]	71.89(5.28)[a]	28.78(4.27)[a]	51.09(5.58)[a]
Forb	0.93(0.29)[a]	55.29(4.86)[b]	36.58(2.44)[c]	33.23(4.08)[ac]	26.02(6.06)[ac]	43.56(4.25)[a]	28.93(3.98)[b]
Woody[A]	0.00(0.00)	0.04(0.05)	1.42(0.47)	0.69(0.40)	0.66(0.58)	20.84(2.14)[a]	20.75(3.24)[a]
Bare Ground	95.06(2.56)[a]	36.74(3.56)[b]	7.90(1.78)[c]	11.43(4.65)[c]	6.20(1.67)[c]	17.77(2.25)[a]	12.02(3.23)[a]
Mid-Canopy	---	---	---	---	---	18.68(2.51)[a]	11.79(2.26)[a]
Upper-Canopy	---	---	---	---	---	69.68(4.65)[a]	79.88(3.34)[a]

[A]Percent woody coverage did not differ between habitats.

Table 9. Significance levels from PROC GLM analysis of the average brood home range estimates in LSWA (n=8) and HTA (n=4) in southeastern, Iowa, in 2003 and 2004 with treatment contrasts for study area (LSWA vs. HTA) and year (2003 and 2004).

	Area[a]	Year[a]	Area*Year[a]
95% Home Range[b]	0.078	0.203	0.149
50% Home Range[b]	0.055	0.034	0.062

[a] $F_{1,8}$ statistics.
[b] Log transformed for analysis.

Table 10. Average (SE) distance (m) between consecutive brood location estimates at 2 and 4 weeks of age and average (SE) distance (m) between a nest site and the center of a brood 50% home range estimate in LSWA and HTA in southeastern Iowa, USA, in 2003 and 2004.

	2003		2004		Areas and Years
	LSWA	HTA	LSWA	HTA	Pooled
Distance (m) Between Consecutive Brood Locations					
2-Weeks of Age	111.74(21.73) (n = 4)	149.27(104.28) (n = 2)	150.73(19.59) (n = 6)	111.50(12.06) (n = 5)	129.63(13.31) (n = 17)
4-Weeks of Age	146.06(31.42) (n = 3)	266.90(n/a) (n = 1)	145.50(22.04) (n = 5)	128.64(26.05) (n = 3)	151.54(16.25) (n = 12)
Distance (m) from Nest to Center of 50% Home Range	149.85(72.60) (n = 3)	498.59(n/a) (n = 1)	365.40(93.04) (n = 5)	265.46(119.99) (n = 3)	297.63(56.61) (n = 12)

Table 11. Significance levels from PROC GLM analysis of the average distances traveled by broods between consecutive brood locations in LSWA (n=10) and HTA (n=7) in southeastern, Iowa, in 2003 and 2004, with treatment contrasts for study area (LSWA vs. HTA) and year (2003 and 2004).

	Area	Year	Area*Year
Distance Traveled Between Consecutive Brood Locations			
2 Weeks[a] (LSWA n=10; HTA n=7)	0.978	0.984	0.223
4 Weeks[b] (LSWA n=8; HTA n=4)	0.164	0.075	0.077
Nest to 50% Home Range[b] (LSWA n=8; HTA n=4)	0.368	0.948	0.124

[a]$F_{1,13}$ statistics.
[b]$F_{1,8}$ statistics.

Table 12. Significance levels from PROC GLM analysis of the proportion of available and used habitat types within available habitat polygons in LSWA (n=10) and HTA (n=6) with treatment contrasts for study area (LSWA vs. HTA) and week (2 weeks (n= 16) vs. 4 weeks (n=12)) effects in 2003 and 2004 in southeastern, Iowa, USA.

	Availability[a]			Use		
	Area	Week	Area*Week	Area	Week	Area*Week
Total Area	0.240	0.624	0.994	---	---	---
Habitat[e]						
Cornfield	0.026	0.960	0.914	0.237[b]	0.333[b]	0.421[b]
Small Grain	0.056	0.902	0.749	0.012[a]	0.456[a]	0.732[a]
Grassland	0.002	0.317	0.744	0.855[a]	0.768[a]	0.921[a]
Pasture	0.005	0.253	0.258	0.084[c]	0.517[c]	0.971[c]
Roadside	0.012	0.058	0.416	0.618[d]	0.227[d]	0.335[d]
Timber[c]	0.317	0.521	0.995	0.186[a]	0.066[a]	0.287[a]

[a] $F_{1,24}$ statistics.
[b] $F_{2,6}$ statistics.
[c] $F_{1,14}$ statistics.
[d] $F_{1,19}$ statisitcs.
[e] Arcsine transformed for analysis.

Table 13. Sum of ranks for differences in use of habitat types in brood available habitat polygons and availability of habitat types within the entire study areas (i.e., second order habitat selection) in LSWA and HTA in southeastern, Iowa in 2003 and 2004. Large sums indicate greater use by broods in comparison to other habitat types. Habitat type ranks with dissimilar superscripts are considered significantly different ($\alpha = 0.05$).

	Habitat Type						
	Cornfield	Small Grain	Grassland	Pasture	Roadside	Timber	P-value[a]
Brood Age							
2 weeks							
LSWA (n=10)	21^{a}	46^{b}	44^{b}	26^{a}	43^{b}	30^{a}	0.003
HTA (n=6)	13^{a}	12^{a}	31^{b}	25^{bc}	21^{ac}	24^{bc}	0.011
4 weeks							
LSWA (n=8)	20^{a}	37^{b}	35^{b}	18^{a}	34^{bc}	24^{ac}	0.019
HTA (n=4)	9	9	16	22	13	15	0.103

[A] H_0: each rank ordering of habitats for each brood is equally likely.

Table 14. Sum of ranks for differences in use and availability of habitat types within brood available habitat polygons (i.e., third order selection) in LSWA and HTA in southeastern, Iowa in 2003 and 2004. Large sums indicate greater use by broods in comparison to other habitat types. Habitat type ranks with dissimilar superscripts are considered significantly different ($\alpha = 0.05$).

	Habitat Type						
	Cornfield	Small Grain	Grassland	Pasture	Roadside	Timber	P-value[a]
Brood Age							
2 weeks							
LSWA (n=10)	---	44[a]	24[b]	26[b]	37[a]	19[b]	<0.001
HTA (n=6)	16.5	22	21	21	28.5	15	0.903
4 weeks							
LSWA (n=8)	---	31[a]	22.5[a]	23.5[a]	31[a]	12[b]	0.007
HTA (n=4)	17	11	15	8	---	9	0.099

[A]H_0: each rank ordering of habitats for each brood is equally likely.

Table 15. Negative binomial regression predicting the amount of habitat patch use by broods in relation to brood age, habitat type, and patch microhabitat vegetation characteristics (see Table 1 for descriptions) on LSWA in southeastern, Iowa, 2004.

Parameter	DF	Estimate	SE	X^2	P-value	Likelihood Ratio	R^2
Intercept	1	-1.05	2.91	0.13	0.717	19.83	0.290
Week 2[a]	1	1.51	0.71	4.25	0.039		
Week 4[a]	0	0.00	0.00	---	---		
Cornfield[b]	1	3.30	3.78	0.76	0.383		
Small Grain Structure[b]	1	1.55	1.30	1.36	0.244		
Grassland[b]	1	0.01	0.87	0.00	0.987		
Roadside[b]	0	0.00	0.00	---	---		
RP	1	0.01	0.02	0.16	0.692		
TC	1	-0.02	0.03	0.36	0.548		
Forb	1	0.03	0.02	2.64	0.104		
Woody	1	0.19	0.19	0.97	0.324		
BG	1	-0.04	0.02	2.88	0.090		
LD	1	0.02	0.02	0.88	0.349		
Dispersion	1	2.16	0.62	---	---		
LR contrasts[c]							
Cornfield vs. small grain	1	---	---	0.32	0.571		
Cornfield vs. grassland	1	---	---	0.82	0.367		
Small grain vs. Grassland	1	---	---	2.18	0.140		

[a]Week 4 is the class variable with the highest value, therefore week 2 is compared to week 4 to test the null hypothesis that coefficients are equal to zero.
[b]Roadside is the class variable with the highest value, therefore all other habitat types are compared to roadside to test the null hypothesis that all coefficients are equal to zero.
[c]Likelihood ratio contrast tests; H_0: All coefficients are equal to zero.

Table 16. Negative binomial regression predicting the amount of habitat patch use by broods in relation to brood age, habitat type and patch microhabitat vegetation characteristics (see Table 1 for descriptions) on HTA in southeastern, Iowa, USA, in 2004.

Parameter	DF	Estimate	SE	X^2	P-value	Likelihood Ratio	R^2
Intercept	1	6.00	8.41	0.51	0.476	4.17	0.106
Week 2[a]	1	-2.41	4.24	0.34	0.557		
Week 4[a]	0	0.00	0.00	---	---		
Small Grain Structure[b]	1	-0.26	3.37	0.01	0.939		
Grassland[b]	1	-2.23	2.45	1.03	0.310		
Pasture[b]	1	-2.01	3.14	0.44	0.508		
Roadside[b]	0	0.00	0.00	---	---		
RP	1	-0.03	0.06	0.35	0.556		
TC	1	0.02	0.08	0.08	0.771		
Forb	1	0.02	0.04	0.21	0.647		
Woody	1	0.30	0.43	0.61	0.436		
BG	1	-0.06	0.07	0.69	0.408		
LD	1	-0.10	0.08	1.46	0.227		
Dispersion	1	5.49	2.10	---	---		
LR contrasts[c]							
Small Grain vs. Grassland	1	---	---	0.39	0.532		
Small Grain vs. Pasture	1	---	---	0.22	0.639		
Grassland vs. Pasture	1	---	---	0.02	0.887		

[a]Week 4 is the class variable with the highest value, therefore week 2 is compared to week 4 to test the null hypothesis that coefficients are equal to zero.

[b]Roadside is the class variable with the highest value, therefore all other habitat types are compared to roadside to test the null hypothesis that all coefficients are equal to zero.

[c]Likelihood ratio contrast tests; H_0: All coefficients are equal to zero.

Table 17. Negative binomial regression predicting the amount of habitat patch use by broods in relation to brood age, habitat type and presence of management techniques in LSWA in southeastern, Iowa, 2004.

Parameter	DF	Estimate	SE	X^2	P-value	Likelihood Ratio	R^2
Intercept	1	-1.17	0.85	1.89	0.169	13.67	0.197
Week 2[a]	1	1.86	0.73	5.79	0.016		
Week 4[a]	0	0.00	0.00	---	---		
Cornfield[b]	1	-0.69	1.99	0.11	0.737		
Small Grain Structure[b]	1	0.40	0.78	0.24	0.622		
Grassland[b]	1	-0.74	0.95	0.62	0.432		
Roadside[b]	0	0.00	0.00	---	---		
Disk/Spray Strips	1	1.20	0.86	2.07	0.150		
2002 Burn	1	-0.46	1.01	0.21	0.650		
2003 Burn	1	2.02	0.94	5.70	0.017		
2004 Burn	1	-2.50	1.56	2.50	0.114		
Dispersion	1	2.41	0.69	---	---		
LR contrasts[c]							
Cornfield vs. Small Grain	1	---	---	0.28	0.594		
Cornfield vs. Grassland	1	---	---	0.00	0.983		
Small Grain vs. Grassland	1	---	---	2.54	0.111		

[a]Week 4 is the class variable with the highest value, therefore week 2 is compared to week 4 to test the null hypothesis that coefficients are equal to zero.

[b]Roadside is the class variable with the highest value, therefore all other habitat types are compared to roadside to test the null hypothesis that all coefficients are equal to zero.

[c]Likelihood ratio contrast tests; H_0: All coefficients are equal to zero

FIGURE LEGENDS

FIGURE 1. Example of an available brood habitat polygon with one 210 m buffer surrounding a brood location. The available habitat polygon is formed by merging the 210 m buffers surrounding all 14 brood locations collected during a 2-week interval.

FIGURE 2. Example of used and available habitat of a single brood used in second order brood habitat selection on LSWA. The entire study area is designated as available habitat and the brood available habitat polygon is designated as used habitat.

FIGURE 3. Example of used and available habitat of a single brood used in third order brood habitat selection on LSWA. The available brood habitat polygon is designated as available habitat and the proportion of used habitat is calculated by summing the number of brood locations within each habitat type and dividing by the total number of brood locations.

FIGURE 4. Mean proportion available of habitat types within 2 and 4-week stage brood available habitat polygons on LSWA (n = 10) and HTA (n = 6) in southeastern Iowa, USA, 2003 and 2004.

FIGURE 5. Mean proportion used of habitat types within 2 and 4-week stage brood available habitat polygons on LSWA (n = 10) and HTA (n = 6) in southeastern Iowa, USA, 2003 and 2004.

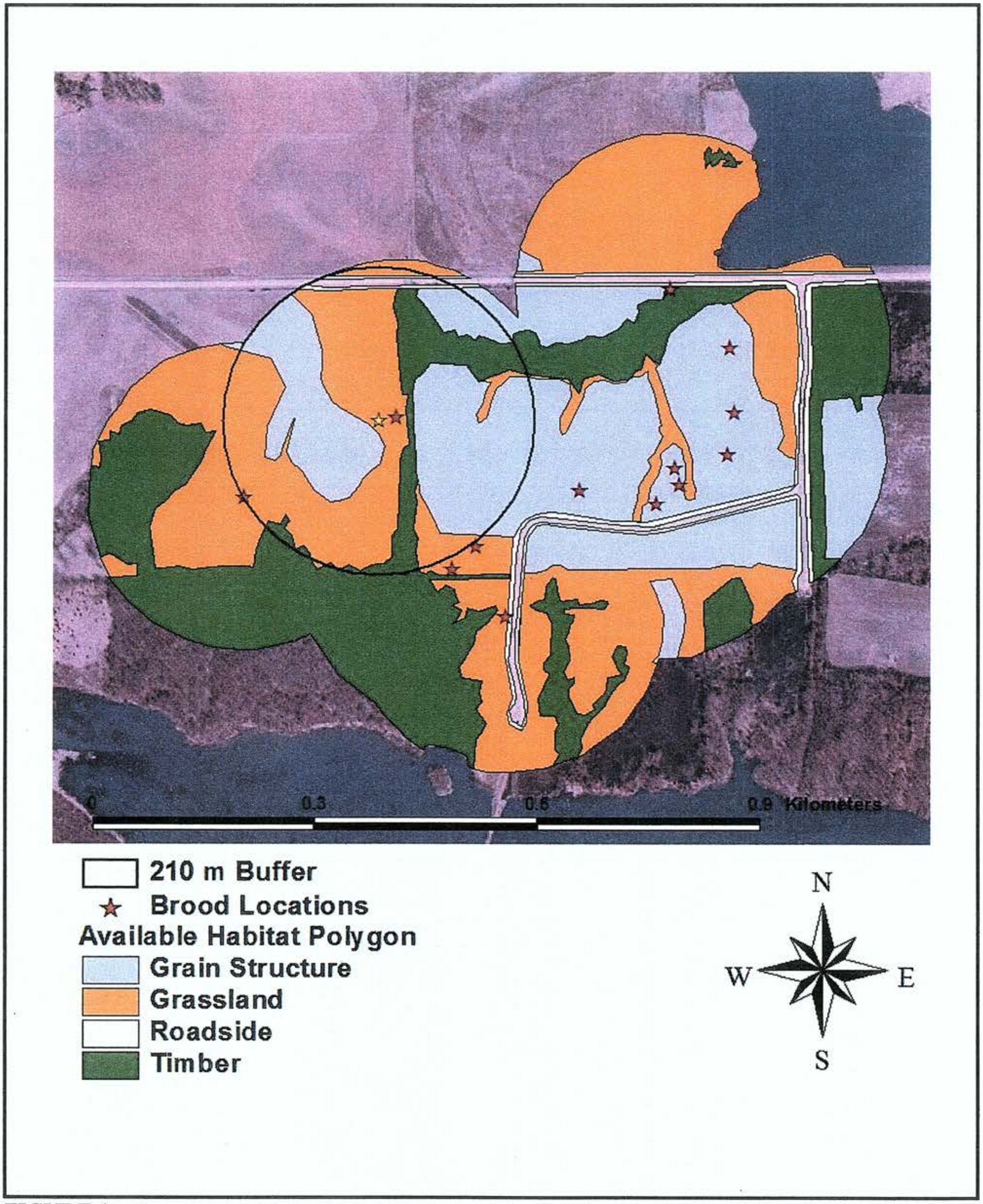
0
0.3
0.6
0.9 Kilometers
210 m Buffer
Brood Locations
Available Habitat Polygon
Grain Structure
Grassland
Roadside
Timber
N
W
E
S

FIGURE 1.

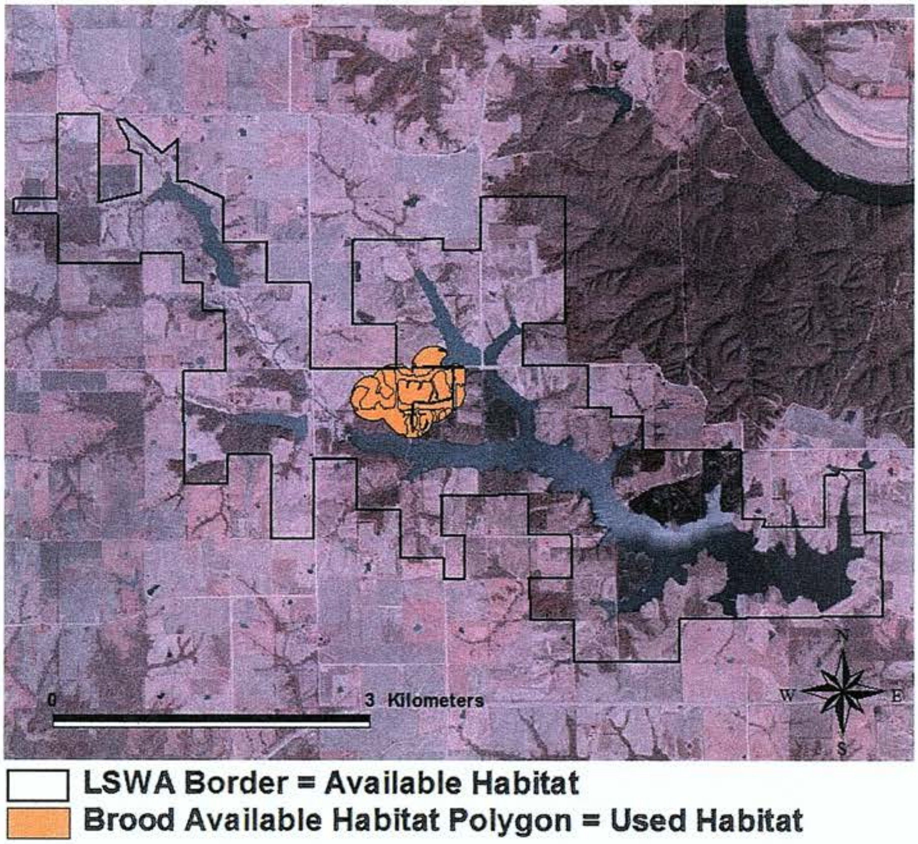
0
3 Kilometers
N
W
E
S
LSWA Border = Available Habitat
Brood Available Habitat Polygon = Used Habitat

FIGURE 2.

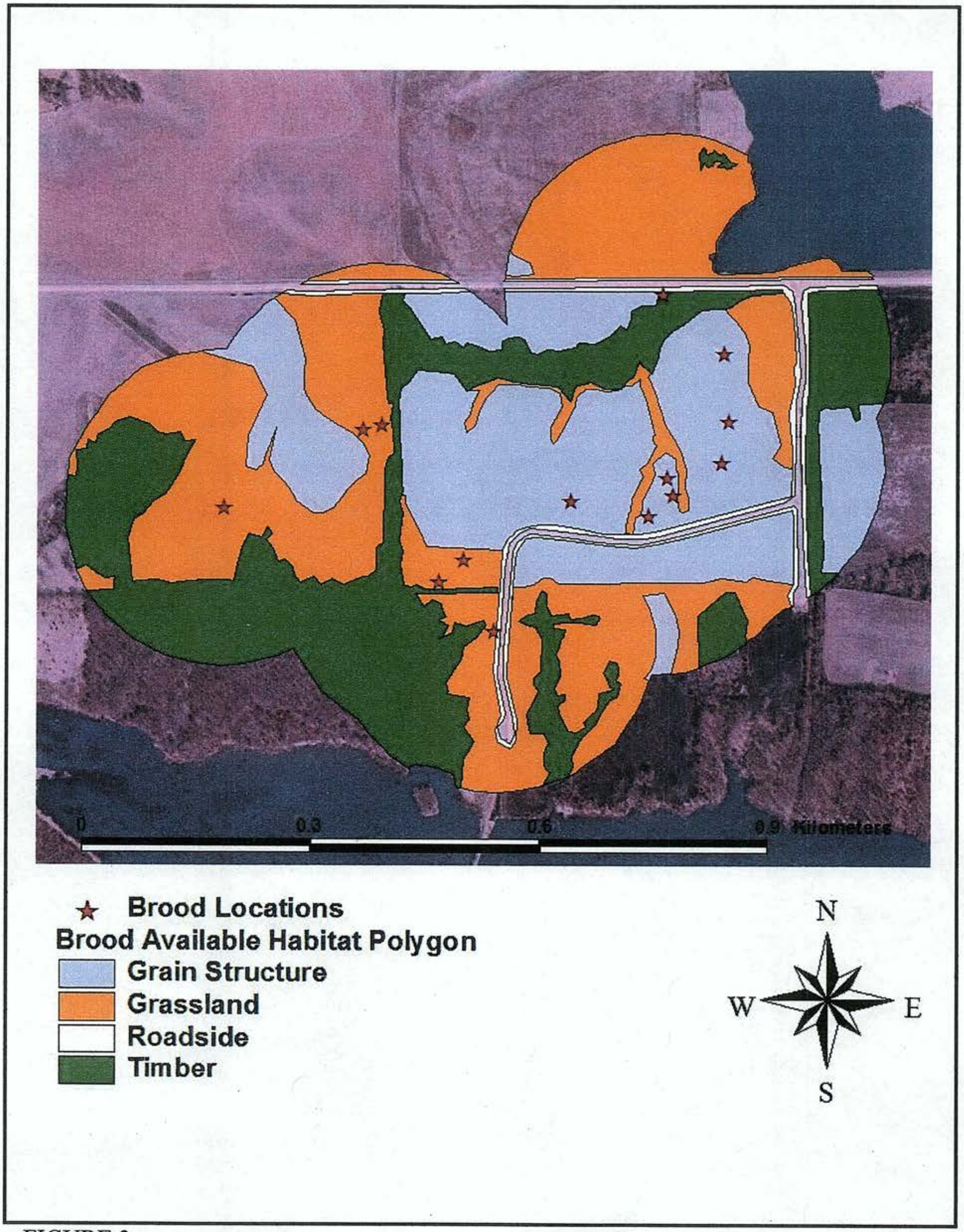
0
0.3
0.6
0.9 Kilometers
Brood Locations
Brood Available Habitat Polygon
Grain Structure
Grassland
Roadside
Timber
N
W
E
S

FIGURE 3.

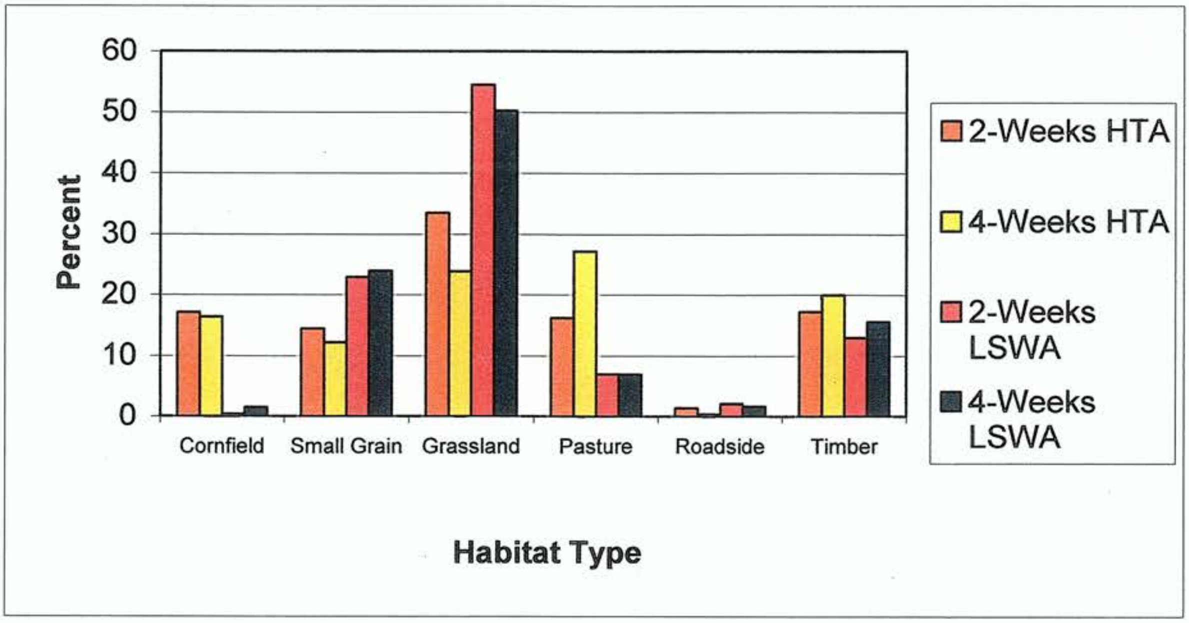

FIGURE 4.

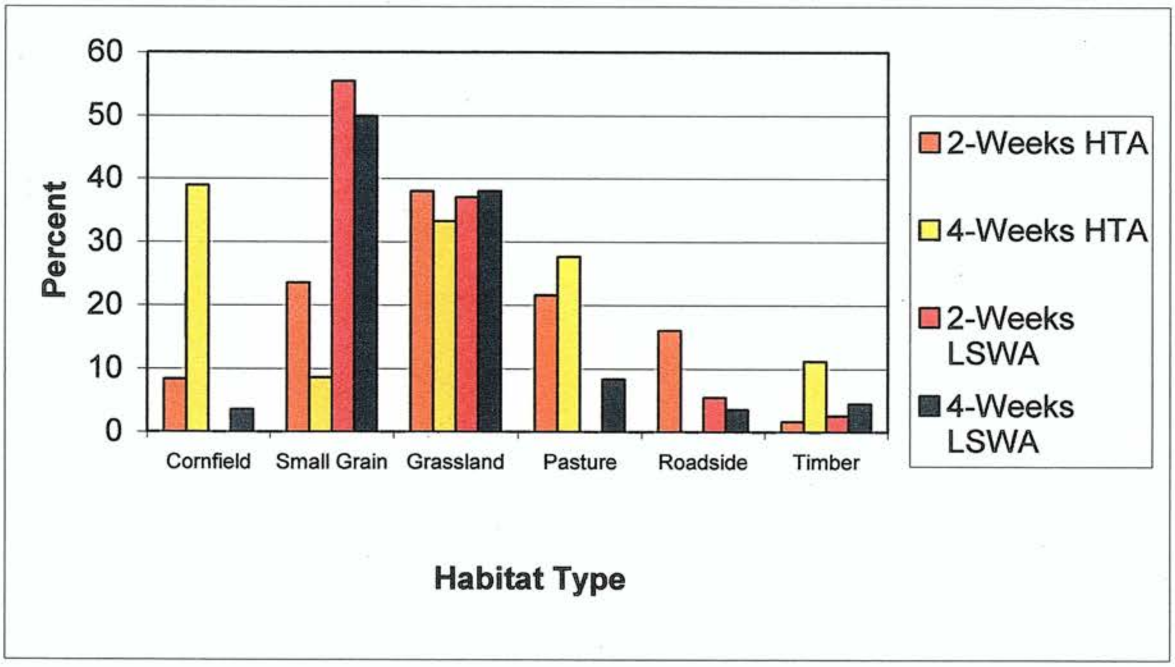

FIGURE 5.

CHAPTER 4. GENERAL CONCLUSIONS

Identification of northern bobwhite nest success in relation to landscape spatial patterns and habitat composition-- I monitored 42 nests in 2003 (n = 11) and 2004 (n = 31). Twenty nests were monitored on LSWA and 22 on HTA, 28% of which were incubated by males. Laying initiation dates were bimodal, peaking in late May and July. Nest density was highest in roadside habitats, although the largest percent of nests was found in grassland habitats. In 2003, nest success rates were significantly higher on LSWA, although this should be considered an artifact of the low number of monitored nesting attempts. In 2004, nest success rates were similar between areas (LSWA = 48.47%, HTA = 43.03%) and were slightly higher than bobwhite nest success rates previously reported in the upper mid-west (Klimstra 1950, Klimstra and Roseberry 1975, Burger et al. 1995).

Microhabitat characteristics, landscape composition and spatial pattern within 210 m of a nest, and applied management techniques on LSWA did not have a measurable effect on nest success. The management techniques utilized on LSWA, such as strip disking and edge feathering, largely focus on enhancing the quality of brooding and escape cover (Daily and Hutton 2003, Greenfield et al. 2003), and therefore are less likely to affect nest success. Although there was nearly twice the amount of available grassland habitat on LSWA than on HTA, the landscape within 210 m of a nest contained at least 30% grassland on both areas. This suggests that bobwhite may in fact make nest site selection choices on the landscape scale, even though this may not ultimately affect success.

The similarity of nest success rates, adult survival estimates, and the lack of differences in microhabitat and landscape metrics surrounding successful and unsuccessful nests on both LSWA and HTA give support to the usable space hypothesis (Guthery 1997). As applied habitat management techniques did not prove to enhance nesting success on areas that were already supporting quail populations, managers should focus on creating additional usable space to increase bobwhite abundance. Prescribed burning, strip disking, and edge feathering should be used to maintain areas that have already proven to be suitable bobwhite habitat. Future investigations of nest success in relation to landscape composition and spatial patterns should include bobwhite abundance estimates and comparisons between managed and unmanaged landscapes to further test the validity of the usable space hypothesis.

Northern bobwhite brood habitat selection in relation to landscape spatial patterns and habitat composition--Seventeen broods were monitored on LSWA and HTA in 2003-04, 12 of these were monitored for the entire 28 days. Apparent chick survival rates in 2003 and 2004 were similar between LSWA (71.74%, n = 7) and HTA (67.42%, n = 6), however brood amalgamation rates have been reported to be as high as 51.7% (Faircloth et al. 2005), therefore the chick survival estimates are likely inflated and unreliable. Distance between consecutive brood locations and the 50% home range estimates were similar between areas suggesting that habitat and food resources within approximately 300 m of a nest were sufficient to satisfy brooding necessities on both areas.

At the home range scale, broods on LSWA and HTA used habitat types differently. At all ages, broods on LSWA selected for small grain structure, grassland, and roadside habitats, while on HTA, broods simply avoided cropfields. At the within home range scale, 2-week old broods on LSWA avoided timber habitat and selected for early successional stage habitat, specifically habitat with a high percentage of forbs. At 4 weeks of age, the early successional habitats that provided a greater diversity and abundance of forbs and therefore a greater diversity of invertebrates, lessened in importance as chick mobility, thermoregulation, and dependence on invertebrates became less problematic. Broods at 4 weeks of age no longer selected for small grain structure habitats but continued to avoid timber habitats.

The percent of forb canopy cover was a significant predictor of brood use on LSWA, as were fields burned the previous year. Vegetation composition of a field burned in the previous year likely consists of high percentages of forbs that not only contain abundant invertebrates, but also provide screening cover from predators. Additionally, ground litter is removed during burns, which in turn provides the bare ground necessary for young chicks. There was no statistical evidence on HTA for brood habitat selection at the within home range scale. The lack of selection for patches within the home range and the lack of microhabitat variables as significant predictors of brood use suggest that broods on HTA are selecting for habitat only at the home range scale and that patch use within the home range is random.

The relationship between invertebrate abundance and diversity and habitat type should be included into future research investigating brood habitat selection. Precise chick survival estimates are also needed in order to relate habitat selection with overall fitness. However, long-duration radio transmitters of sufficiently small size will likely be required to obtain accurate chick survival estimates that are not confounded by brood amalgamation.

LITERATURE CITED

Burger, L.W. Jr., E.W. Kurzejeski, T.V. Dailey, and M.R. Ryan. 1993. Relative invertebrate abundance and biomass in conservation reserve program plantings in Missouri. Pages 102-108 *in* K.E. Church and T.V. Dailey, eds. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

______. M.R. Ryan, T.V. Dailey, and E.W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59(3): 417-426.

Daily, T., and T. Hutton. 2003. On the edge: a guide to managing land for bobwhite quail. Conservation Commission of the State of Missouri. Columbia, MO.

Faircloth, B.C., W.E. Palmer, and J.P. Carroll. 2005. Post-hatching brood amalgamation in northern bobwhites. Journal of Field Ornithology 76(2): 175-182.

Greenfield, K.C., M.J., Chamberlain, L.W. Burger, Jr., and E.W. Kurzejeski. 2003. Effects of burning and discing conservation reserve program fields in improve habitat quality for northern bobwhite (Colinus virginianus). American Midland Naturalist 149(2): 344-353.

Guthery, F.S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61(2): 291-301.

Hurst, G.A. 1970. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Proceedings of the Tall Timbers conference on ecological animal control by habitat management. 2: 173-183.

Klimstra, W.D. 1950. Bob-white quail nesting and production in southeastern Iowa. Iowa State College Journal of Science. 24:385-395.

______. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Manley, S.W., R.S. Fuller, J.M. Lee, and L.A. Brennan. 1994. Arthropod response to strip disking in old fields managed for northern bobwhites. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 48:227-235.

Palmer, W.E., M.W. Lane, II, and P.T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65(4):861-870.

Roseberry, J.L., and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, IL, USA.

Rosene, W. 1969. The bobwhite quail: Its life and management. Rutgers University Press. New Brunswick, NJ.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, NY, USA.

ACKNOWLEDGEMENTS

I thank the Iowa Cooperative Fish and Wildlife Research Unit and the Iowa Department of Natural Resources for funding this study. Specifically, I would like to thank Todd Bogenschutz for his assistance with study design and logistics. I also greatly appreciate Chuck Steffen for his valuable advice and experience, and especially for his dedication and commitment to restoring bobwhite populations. Additionally, I thank them both for introducing me to the excitement and beauty of a dog on point.

I appreciate all the early morning brood flushes, the long days of telemetry and veg sampling, and the late nights spent night-netting that my wonderful field technicians sacrificed to this project. Aaron Lange, Keith Wilcox, Jim Chmielenski, Ben Williams, Mac McInroy, and Ember Hall were essential to the success of this study.

I am grateful to Bill Clark and Rolf Koford for their helpful advice on study design and data analysis. I am particularly grateful to my major advisor, Dave Otis, for his invaluable guidance throughout this study. His advice and thoughtful discussions made it possible for me to navigate through the world of statistics. I am especially thankful for his limitless patience and his obvious dedication to helping graduate students successfully transition into professional biologists.

I would also like to thank Brenda VanBeek for her assistance, kindness, and humor. She truly helped my experience at Iowa State run smoothly. I also thank Todd Hanson for all his help with GIS and for his calm and caring demeanor. I am grateful to my fellow graduate students who helped make this experience fun and enjoyable and for all their wonderful advice and laughter.

I thank my good friends Mindy Boor, Allison Domingues, Tracy Masters, and Stefanie Stewart for their encouragement and friendship. They will forever be a part of my life no matter where in the world my love for wildlife takes me. And most of all, I want to thank my family for providing support, hope, and laughter and for always knowing which one I needed. Finally, I especially want to thank my father who taught me the honesty of hard work. The memory of his love and support will carry me throughout my life.